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GEOLOGICAL SURVEY OF OHIO
FOURTH SERIES, BULLETIN 21

GEOLOGY OF MUSKINGUM COUNTY

By

WILBER STOUT

(Reprinted without revision 1945)

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HON. JAMES M. COX, *Governor of Ohio:*

DEAR SIR:—I transmit herewith Bulletin 21, entitled Geology of Muskingum County. This county is very important from an industrial viewpoint and its geological resources are large. The work has been done in detail and with much care by Wilber Stout and assistants, and I am confident that it will be frequently consulted.

Respectfully submitted,

J. A. BOWNOCKER,
State Geologist.

Columbus,
August, 1, 1918.

DR. J. A. BOWNOCKER, *State Geologist:*

DEAR SIR:—I submit herewith the report on the geology of Muskingum County. In the summer of 1916 field work was assigned in Newton, Springfield and Washington townships to Kenneth C. Cottingham; in Clay and Brush Creek townships to Chester A. Baird; in Bluerock, Meigs, Salt Creek, Rich Hill, Union and Perry to Charles R. Schroyer and Raymond E. Lamborn, and in the remainder of the area to the writer. In the summer of 1917 Mr. Lamborn and the writer completed the stratigraphic work, sampled the coal beds, and finished mapping the oil and gas wells. The work includes a detailed study of the rock strata with special reference to their economic uses.

Respectfully submitted,

WILBER STOUT,
Assistant Geologist.

Columbus,
July 12, 1918.

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CHAPTER I

PHYSIOGRAPHY

INTRODUCTION

The beautiful valley of the Muskingum River early attracted the daring hunters and hardy settlers who in 1797 built the first cabins on the present site of Zanesville. The town was laid out in 1799 and soon became a prosperous business center because of the natural advantages of navigable streams, heavy forests, fertile valleys, and mineral wealth. In 1802 the manufacture of common brick from the surface clays initiated the ceramic industry in this region.[1] Beginning with the making of crude plates, cups, and saucers by Samuel Sullivan in 1908, from native coal formation clays, the stoneware industry advanced rapidly both in the towns and in the rural districts, until the region became one of the recognized centers for this grade of ware in the United States. Other allied branches of clay working such as the manufacture of face brick, paving block, art pottery, and mosaic tiling gradually developed to prime importance and the products are now widely known for their quality or for their beauty. The natural resources have been intelligently used for the development of the region and Muskingum County is of special interest for its clays, coals, limestones, sandstones, shales, sands and gravels.

LOCATION AND AREA

Muskingum County is located in the east-central part of the State and is bounded on the north by Coshocton County, on the east by Guernsey and Noble counties, on the south by Morgan and Perry counties and on the west by Perry and Licking counties. It lies in the central part of the Muskingum Basin and is well within the area of the coal formation rocks. According to the latest estimate of the Federal Government, the area of Muskingum County is 650 square miles. It is surpassed in size only by Ashtabula and Licking counties.

PHYSIOGRAPHY[2]

A brief sketch of the early history of the surface and rocks of Muskingum County is necessary in order to understand later changes and

[1]History of Muskingum County, J. Hope Sutor.

[2]This bulletin, when planned, was to include a comprehensive survey of the physiography of the county, but Professor T. M. Hills, to whom the work was assigned, was called into military service, so it seemed best not to withhold publication of the bulletin until such time as his work could be completed. The present chapter does little more than point out the salient features.

modifications. All the consolidated rocks now appearing at the surface are of sedimentary origin, that is, they were laid down in or by the agency of water. With few exceptions, the beds were deposited in the sea or in extensive marshes during a period of general subsidence or sinking of the area. The various rock-building processes acting

MAP I—The position of Muskingum County in Ohio.

through the latter part of the Mississippian period, through the Pennsylvanian, and through the early part of the Permian, finally accumulated the thick mass of strata that now appears at the surface in this county. Crustal movements then took place and these newly formed rocks were slowly elevated above the level of the waters. With this event the various degrading agencies such as rain, winds, weathering, solution, etc., became active. Streams with additional leveling forces such as

corrasion and wash were formed and they carried loads of loosened material to the sea. Through such agencies the region in Cretaceous time was reduced to a base level or to a plain most of which was not far above tide. Again crustal movements elevated the surface of this ancient plain far above its former level. The high plain thus formed is known as the Allegheny Plateau and its remnant may still be recognized by the even sky line observed from the tops of the highest hills. With the rising of the land degrading agencies again became active in carving valleys and reducing uplands. After a long time this work was modified greatly by the action of the vast Illinoian and Wisconsin ice sheets which advanced into or near the western part of the county and which reversed or greatly modified many of the former drainage lines. The present streams with other agencies are now actively at work in reducing this old Allegheny Plateau to base level or to a low-lying plain.

Relief

The chief relief features of Muskingum County are the long lines of rather rugged hills separated by the ribbon-like plains along the courses of the more important streams. The region is a part of the great Allegheny Plateau, the plain of which has an elevation of approximately 1,200 feet, as is indicated by the summits of the main ridges. The streams aided by other degrading agencies have thoroughly intrenched their courses in the coal formation rocks and have thus reduced much of the land far below its original level. The dissected character of the region is a disadvantage in building roads and railroads and for agricultural pursuits, but it has aided in bringing to light many important mineral beds, such as coals, clays, shales, and limestones upon which much of the industrial activity depends.

Hills and Uplands

The most elevated tracts of land in Muskingum County are in the eastern part of the area along the main water divide between the small streams that flow westward into the Muskingum River and those that flow eastward into Wills Creek and southward into Meigs Creek. The main ridges in southern Bluerock Township have elevations of more than 1,100 feet and some of their high knobs reach 1,200 feet. These ridges are rather narrow and moderately steep and are built up, in the main, of fresh-water limestones and calcareous clay shales which are not especially resistant to degrading agencies. In the extension northward of these ridges and knobs the decrease in elevation is marked and in the Salt Creek Basin in Salt Creek Township it amounts to nearly 200 feet. The highest knob in Muskingum County is found just north of the village of High Hill, in Section 3, Meigs Township, and it has an elevation of 1,286 feet above tide. On its slopes

rise Buffalo Fork and Kent Run, tributaries of Salt Creek; Starrett Creek and Guyst Fork, tributaries of Meigs Creek; and Miller Creek a tributary of Wills Creek. The resistance of this ridge to the leveling agencies at work since the elevation of the Allegheny Plateau above the sea is evidently due to its position, which is far removed from any of the main lines of drainage, and to the presence of the massive Gilboy sandstone which outcrops near the 1,200-foot contour. This ridge in its extension southeastward to Zeno in Section 23, thence eastward into Noble County, and southward into Morgan County, also retains an elevation above 1,100 feet. The wide flats and terraces along the ridges in the Meigs Creek Basin in southwestern Meigs and southeastern Bluerock townships are due in the main to the character of the rock strata upon which the various forces have been active. In this region the soft clay shales between the Skelley limestone and the Pittsburgh coal have yielded far more rapidly than the gray shales and shaly sandstones below this limestone member. Much excellent farming land has thus been developed through this process. Another conspicuous topographic feature in Bluerock Township is the prominent escarpments and cliffs along the Muskingum River south of Gaysport which are due to the resistant character of the massive Cow Run sandstone. Where the member outcrops along the small streams the valleys are gorge-like and very rough. Differential action of the degrading agencies on the rock strata has also produced large tracts of gently rolling lands very suitable for farming, along the ridges in parts of Salt Creek, Rich Hill, and Union townships. The best of these lands are found along the outcrop of the upper part of the Conemaugh and the lower part of the Monongahela formations in which the conspicuous rocks are clay shales and marly limestones. The main water divide that extends northward across central Rich Hill and Union townships, although it is a broad flat ridge and is composed of such yielding material, has an elevation of approximately 1,100 feet. The broad ridges in many localities in Highland, Monroe, Adams, and Salem townships are in part traced to the influence of massive sandstones such as the Buffalo, the Mahoning, or the Freeport. Steep slopes often terminating in cliffs are found where the massive Clarion sandstone outcrops along the Muskingum River in northeastern Madison and northwestern Adams townships and from Gilbert to Zanesville in Washington Township.

In Muskingum County west of the Muskingum River the various forces of weathering and erosion have been very active in lowering the old surface, for at present but few of the ridges have an elevation of 1,000 feet and not many of the knobs reach 1,100 feet. The highest point is in Section 13, Clay Township, which is about 1,170 feet. Aside from the preglacial waterways the most prominent topographic feature in the northwestern part of the county is the ridge known as The Highlands which extends from Nashport through northeastern Licking,

southeastern Jackson, and central Cass townships to Dresden and which throughout most of its extent is more than 1,000 feet in altitude. Irish Ridge in northern Cass and Graham Ridge in northeastern Jackson townships also have about the same measurements. All these ridges are usually narrow and have rather steep slopes. The prominent rocks along the summits which appear to have effectively resisted the leveling agencies are limestones, especially the Putnam Hill and the Ferriferous. The most prominent bed modifying the relief in the western parts of Jackson and Licking townships is the Massillon sandstone which locally is so massive and weather resistant as to form steep bluffs along the hillsides and ridges. The round knob topography which is rather conspicuous along the ridge west of Dresden is occasioned by differential weathering of a thick sandstone underlain by the Middle Kittanning coal and its associated clays. The task of base-leveling is well advanced along the old preglacial waterways in parts of Licking, Muskingum, and Falls townships, for the hills are low and well rounded and the valleys wide and gently sloping. The influence of the character of the strata in retarding the action of degrading agencies is well shown on Flint Ridge where the Ferriferous member assumes the phase of hard flint and is several feet in thickness. Along its eastern border near Poverty Run in Hopewell Township, the flint lies near the 1,060-foot contour and has on the knobs a covering of not more than 60 feet. In its extension westward the ridge rises at practically the same rate as the flint until Section 20, Franklin Township, Licking County, is reached, where this rock has an elevation of about 1,240 feet and a covering of less than 20 feet. The ridge is rather wide and in places very flat. The lateral ridges and isolated knobs with a capping of flint or its associated shaly limestone also stand out in bold relief as examples of the same action. Buzzard Glory Knob near Brownsville is one of the most conspicuous of these. The southwestern part of the county has been well dissected by the through-flowing streams and their numerous tributaries and much of the area has been thus considerably reduced below the old plain level. The main ridges have elevations of about 1,000 feet, are well rounded, and have moderate, low gradients. Along them much good farming land is found. In Brush Creek and Harrison townships the ridges are generally narrow, but their slopes are often well terraced, especially along the horizons of the Cambridge limestone, Round Knob shale, and Skelley limestone. The most prominent modifying sandstones in these townships are the Cow Run in the southern part and the Lower Freeport along the Muskingum River in the northern part.

Valley Plains and Terraces

The plains and terraces found along the courses of the through-flowing streams and along those of the larger tributaries are prominent.

Aside from their value for agricultural purposes they afford sites for towns, villages, and country homes and ways for railroads and thoroughfares. The valleys of the present streams, which in general have reached the stage of maturity, are rather wide and those of the preglacial waterways which were also advanced in age are not only broad, but in places basin-like. Fine examples of long, narrow terraces, often one upon another, bordering the flood plain on the one side and the uplands on the other, are present with some regularity along the Muskingum and Licking rivers and Jonathan, Moxahala, Salt, and White Eyes creeks.

The plains along the Muskingum River, which is the master stream in Muskingum County, are nearly 1 mile wide in the nothern part of Cass Township where they enter Muskingum County from Coshocton County, but they expand to about 2 miles in the vicinity of Trinway. This great width of valley, however, should be attributed largely to the work of the preglacial Newark River and not to that of the present stream. From Trinway to Rock Cut the valley averages about four-fifths mile in width, but from here to Zanesville it is scarcely more than half this measurement. The narrow plains bordered by steep walls from Rock Cut to Zanesville indicate that the valley is in a rather youthful stage and that it is largely the work of the present stream. Only narrow tongues of plains, first on one side and then on the other, are present. Aided by preglacial streams the Muskingum River has built up plains about one-half mile in width from Zanesville to Duncan Falls. Fine examples of terraces are found in this area. From Duncan Falls to the Morgan County line the valley is deeply entrenched and narrow, and in many places the width of the flood plains and terraces does not greatly exceed that of the river. Taken as a whole the valley of the Muskingum in Muskingum County is abnormal. In a general way the plains of the stream increase in width and the walls of the valley decrease in height in the upstream direction, or from the Morgan County line on the south to the Coshocton County line on the north. The conditions are thus the reverse from what would be expected of normal streams and are only interpreted through a study of the preglacial drainage ways.

The plains next in importance are those which really belong to the preglacial Newark River, but which are now drained by Wakatomika Creek and its tributary, Black Run. These plains extend from Trinway past Frazeysburg and Black Run into Licking County and average more than a mile in width. Terraces are prominent in parts of the area. The plains along Wakatomika Creek in sections 13 and 8, Jackson Township, average less than one-fifth mile in width and show the work done by the present stream, whereas those in sections 3, 4 and 5, are more than twice this width, but are the resultant of both present and preglacial degrading forces. At present the stream is deepening its bed but little and is widening its valley only in the more restricted parts.

The valley of the Licking River, which is the second largest stream in Muskingum County, shows modifications due also to earlier drainage lines. The plains along this stream from the Muskingum Valley at Zanesville to the mouth of its tributary, Stump Run, near Irville, a distance of more than 10 miles, average less than two-fifths mile in width. Although this part of the valley may be comparatively young, the stream is not especially active in deepening its channel or in widening its plains owing to the large quantity of glacial debris poured into it from headwater sources. From Irville to the Licking County line, a distance of more than 3 miles, the plains along the Licking River are from one-half to more than 1 mile in width and are largely the work of earlier forces. The plains as well as the terraces are composed mainly of glacial material which is from 50 to at least 80 feet in thickness. Preglacial valley plains now poorly drained are also found in the western part of Licking Township. The canal, now abandoned, follows one of these from the Licking Valley at Nashport to the old Newark Valley east of the village of Black Run. Wide basin-like plains, also remnants of former drainage ways, but now poorly dissected, are found in Muskingum Township.

White Eyes Creek in Monroe Township has plains exceptionally broad for a stream of its size as they average nearly two-fifths mile. A regular well-defined system of terraces is present from the mouth of the stream to about 1 mile south of Otsego. The most conspicuous terrace has an elevation of approximately 780 feet and is composed of sand and silty material. The valley of Symmes Creek and those of its important tributaries, North Branch and South Branch, in Madison, Adams, and Salem townships are usually narrow and show no modifications worthy of mention, except that South Branch formerly extended eastward into what is now the headwaters of Salt Creek. The flat plains south of Adamsville are thus largely the work of preglacial degrading agencies.

In the Salt Creek Basin which drains most of Wayne, Salt Creek, Rich Hill, Perry, Union, and Salem townships, the widths of the bordering plains are often out of proportion to the size of the streams. In some localities a small stream has wide and in places basin-like plains, whereas in other regions a larger stream has only narrow, broken, ribbon-like plains for several miles along its course. The correct interpretation of such results requires a study of the early drainage system which had reached a mature stage when modified during glacial time into the present system which is comparatively young. The broad valleys were carved largely by the early streams and the constricted tortuous passages by the present streams. During the reversal of drainage Meigs Creek was but little changed except that it was rejuvenated somewhat which thus caused deepening of its channel and extending its headwaters farther into the uplands. Its bordering plains are generally narrow and rather uniform in width.

The valley of Moxahala Creek from its mouth near South Zanesville to the village of Darlington is gorge-like and tortuous, thus indicating a youthful stage, but from Darlington to Crooksville it is broad, averaging more than one-half mile, and in places well terraced, thus showing the work of early degrading agencies. The plains are built up of material derived from the country rock in the basin and soils are therefore not especially rich when compared with those found along the Muskingum and Licking rivers which head on the glaciated area. The valleys of Jonathan Creek from its mouth near Elizabeth to Fultonham and that of its southern tributary, Buckeye Fork, from Fultonham to the Perry County line average nearly two-fifths mile in width, and were largely completed in the cycle closing with the advent of the glacier. Jonathan Creek from Fultonham to the village of Mt. Perry in Perry County flows through a narrow gorge-like valley along which only narrow isolated tracts of plains have as yet been built. The cycle represented here began not earlier than interglacial time. The plains along Brush Creek which drains most of Brush Creek and parts of Newton and Clay townships are about normal in width and are not conspicuously terraced.

In review, the valley plains of much magnitude in Muskingum County are really the work of preglacial streams which had dissected the land and eroded the valleys to a stage of maturity at the time of the changes of drainage during the glacial period. Many of the valleys were not far different at the close of the preglacial cycle from what they are at present, but others have been greatly modified and a few originated during this great change. The younger valleys formed by the erosion of cols or divides between one basin and another have steep walls and are bordered only by narrow plains, often not wider than the stream itself. Following the reversal of drainage along the major valleys important terraces were formed which were gradually dissected or largely removed as the present stream reached lower levels. This work is not yet completed. These valley plains and terraces are the most valuable farming lands in Muskingum County.

Drainage

Present System

The Muskingum River, which is a through-flowing stream, receives directly or indirectly the water from all of Muskingum County. It enters Cass Township from Coshocton County on the north, flows westward to Dresden, thence southward past Zanesville, Philo, and Gaysport and enters Morgan County. It has a length of 109 miles to which must be added nearly 100 miles for that of its formation streams. The area of the basin is 7,740 square miles.[1] The length of this river in

[1]Tenth Census of the United States 1880, Vol. XVII, Part II, p. 466.

Muskingum County is about 42 miles and the gradient nearly 1 foot 6 inches per mile. The stream flows on bed rock at a number of places between Dresden and the Morgan County line, but most of these are now hid owing to the presence of Government dams. The best exposed rapids at present are at Zanesville where the stream pours over the Lower Mercer limestone and its associated shales and sandstones. Another well-known rapid, but now hid by damming, is at Duncan Falls, where the Clarion sandstone forms the bed rock. The walls of the valley are from 250 to 300 feet high and in places are lined with bold escarpments which often terminate in cliffs. This is especially true of the bordering hills on both sides of the river from Philo to the Morgan County line. This part of the valley is both picturesque and beautiful and well worth visiting by those admiring such touches of nature. Steep hills with occasional cliffs are also locally present on one or both sides of the river from Philo to the Coshocton County line. Besides flood plains the river is bordered by terraces throughout most of its course in the county. The most northern tributary to the Muskingum River is Wills Creek which comes from the east and which joins the main stream in the northwestern corner of Adams Township. Other eastern tributaries, all small streams, are Symmes Creek, Blount Run, Salt Creek, and Dry Riffle Run. The first western tributary to join the river in this area is Wakatomika Creek which flows for some distance in the valley of the old Newark River and unites with the master stream near Dresden. From this village to Zanesville the western tributaries are all small runs draining only a few square miles of area. At Zanesville the Muskingum receives the waters of the Licking River, the main basin of which is in the glaciated region west of this county. Moxahala Creek which rises far to the south in Perry County empties into the Muskingum near South Zanesville. Other western tributaries are Brush Creek, Duncan Run, Back Run, and Bluerock Creek. It is noteworthy that many of the tributaries of the Muskingum River join it in a northward direction, the reverse from that of normally developed laterals.

Wills Creek is formed by the junction near Pleasant City, Guernsey County, of Buffalo Creek which rises in Enoch Township, Noble County, and of Buffalo Fork, which heads in Meigs Township, Muskingum County. From Pleasant City the stream flows northward past Byesville and Cambridge to Kimbolton, thence westward with many deviations through southern Coshocton County and northern Muskingum County to the Muskingum River in the northwestern corner of Adams Township, Muskingum County. The course of the stream is very tortuous and in places the valley is narrow and gorge-like. The area of the basin is 815 square miles,[1] but the part in Muskingum County is approximately 100 square miles. Its tributaries, Collins

[1]Tenth Census of the United States, 1880, Vol. X VII, Part II, p. 466.

Fork and Miller Creek, drain northeastern Meigs Township; Miller and Yoker creeks drain eastern Rich Hill; Crooked Creek eastern Union and southeastern Highland; White Eyes Creek northern Highland, Monroe, and parts of eastern Adams and Salem, and Brelsford Run and Big Run northern Adams. Only about 5 miles of Wills Creek is within Muskingum County and that is found in northwestern Monroe and northern Adams townships. The stream has many flexures and flows in a narrow valley bordered by steep hills. Bed rock is exposed at several places and terraces are conspicuous along most of its course.

Symmes Creek with its tributaries, North Branch and South Branch, drains central Madison, southern Adams, and northwestern Salem townships. They are mature degrading streams, but show some abnormalities. Blount Run drains the northern part of Washington Township. Salt Creek heads in Section 17, Highland Township, flows westward to Section 16, Salem Township, thence southeastward to Section 10, Perry Township, thence southward across Perry and Salt Creek townships, and empties into the Muskingum River near Duncan Falls in Wayne Township. It drains southwestern Highland, southern Salem, Perry, eastern Washington, western Union, Salt Creek, western Rich Hill, eastern Wayne, northwestern Meigs, and northeastern Bluerock townships. It has a length of more than 26 miles and a basin of approximately 145 square miles, being the largest stream entirely within the county. Its course is tortuous and in places its valley is narrow and deeply entrenched. In the constricted parts the stream flows on or not far above bed rock, but in the wider parts it has not cut its channel to former stream levels. The eastern and southern rim of this basin is the highest range of hills in the county, the mean altitude of which is about 1,100 feet. The largest tributaries of Salt Creek are Prairie Fork, Georges Run, Frog Run, Little Salt Creek, White Eyes Creek, Buffalo Fork, Boggs Creek, and Manns Fork.

The small stream, Dry Riffle Run, heads near Ruraldale, flows northwestward and empties into the Muskingum River at Gaysport. It drains only a few square miles of southern Bluerock Township. Meigs Creek, which is an important tributary of the Muskingum River, and which unites with the major stream in the southwestern corner of Center Township, Morgan County, drains southwestern Meigs and southeastern Bluerock townships.

Wakatomika Creek with its tributary Black Run drains most of Jackson, a small area in northwestern Licking, and the northwestern part of Cass townships. It enters the county in the northwestern corner of Jackson Township, flows southeastward to the preglacial Newark River Valley at Frazeysburg, thence follows this plain eastward to the Muskingum River at Dresden. Its course is very tortuous and its valley narrow and gorge-like in the northern part of Jackson Township where the stream flows on or near bed rock. In the old preglacial

valley the bed of the present stream is more than 150 feet above that of former waterways. In this part of its course the gradient is low, hence the stream is sluggish.

The Licking River, which is formed at Newark by the junction of North Fork and South Fork, flows eastward across Madison and Hanover townships, Licking County, thence southeastward across Licking, Hopewell, and Falls townships, Muskingum County, and unites with the Muskingum River at Zanesville. The area of the basin is 703 square miles but that of the part in Muskingum County is about 105 square miles. The length of the stream in this area is nearly 16 miles. The tributaries, all small streams, are, from the north, Stump, Big, Bartlett, and Joes runs, and from the south, Poverty, Timber, and Pratt runs. The most prominent exposures of bed rock along the Licking River are at Zanesville where it flows over the Lower Mercer limestone and at Dillon Falls where it flows over the Massillon sandstone. Throughout most of its course the floor is hid by a thick covering of glacial debris. The valley is constricted from Zanesville to Irville, but its walls are rather low and not especially steep. The gradient is about 3 feet 6 inches per mile which is sufficient to give many riffles and some rapids.

The next important tributary of the Muskingum River is Moxahala Creek which heads near Bristol in Pike Township, Perry County, flows northward across Pleasant, Bearfield, and Harrison townships, Perry County, and across Clay and Newton townships, Muskingum County, and unites with the master stream near South Zanesville. Its course is nearly reversed from that of the Muskingum and its tributaries also have much the same bearing. The course of the stream is exceptionally straight and the valley is mature. Jonathan Creek with its laterals, Kent Run, Thompson Run, and Buckeye Fork, is the only important tributary in Muskingum County. Moxahala Creek receives the drainage from southern Springfield, southern Hopewell, Newton, and western Clay townships. In Newton Township the Maxville limestone forms the bed of Jonathan Creek from Section 9 to Section 13 and that of Kent Run from its mouth at White Cottage to the county line in Section 2. Constricted valleys with steep walls are found along Moxahala Creek from its mouth to Darlington, along Jonathan Creek from Fultonham to the Perry County line, and along Kent Run from Section 12, Newton Township, to Opera in Hopewell Township. The gradient of Jonathan Creek in Muskingum County is about 10 feet to the mile, whereas that of Moxahala Creek is only 4 feet 1 inch per mile.

Brush Creek is another stream in this county that flows in a counter direction to the Muskingum River. It rises in Section 8, Brush Creek Township, flows eastward for about 2 miles, thence nearly due north to the Muskingum River in Section 7. It receives the waters from

central and western Brush Creek and from small areas in eastern Clay and Newton townships. The largest tributaries, all from the west, are Baughman, Turkey, and Goose runs. Small areas in northern Harrison and northeastern Brush Creek townships are drained by Duncan Run, the direction of which is abnormal for a tributary of the Muskingum River. Back Run receives the waters from a few square miles in central Harrison Township, and Bluerock Creek from larger areas in southern Harrison and southeastern Brush Creek townships. Bluerock Creek also flows to the northeast, thus joining the Muskingum River in an upstream direction. These three small streams in Harrison Township flow in deeply entrenched valleys, have steep gradients, and at present are actively engaged in deepening their channels.

Many of the dendritic tributaries to the main stream begin at springs which are perennial or nearly so. Springs are rather numerous near the Mercer horizon along Flint Ridge in Hopewell Township, at the base of the Massillon sandstone in Licking and Jackson townships, at the base of the Buffalo and Mahoning sandstones in Monroe and Highland townships, and of the Cow Run sandstone in southern Harrison and Bluerock townships. Other horizons along which good springs are not uncommon are the Putnam Hill limestone, Clarion sandstone, and Middle Kittanning coal. The well-known spring on Putnam Hill at Zanesville issues from the horizon of the Putnam Hill limestone.

Old Drainage Systems

Muskingum County presents some interesting problems in physiography, especially in the preglacial drainage and in its later modifications. Viewed from the upland regions many of its valleys appear entirely too wide for the work of the streams that now occupy them, whereas others for short distances seem proportionally too narrow and constricted. Moreover, the direction of drainage of some tributaries is reversed from that of the major stream. The explanation of these features involves many factors, the influence of some of which is now difficult to interpret. The drainage of the old Allegheny Plateau which was maturely dissected was first modified by the influence of the Illinoian glacier and later by that of the great Wisconsin. Aside from these, are the more normal changes due to the work of piracy, to the resistance of strata encountered, to the direction of dip of the rocks, to the overloading with sediments, to the removal of barriers, etc. The work of one agent, although of importance in the final results, may be so obliterated or so modified by that of other agencies as to leave but little clue to its identity. The drainage modifications in part have been studied by Read, Tight, Leverett, Davis, Carney, Todd, Mather, and others. In this bulletin only a brief survey of the work will be attempted.

A—View up the Muskingum and across the preglacial Newark valleys from a hill at Symmes Ford, Madison Township. Both valleys are broad and well terraced.

B—In the southern part of the county the Muskingum River flows in a narrow valley bordered by high steep hills. The view shows the river cutting the base of the hill near the mouth of Salt Creek, Wayne Township.

PLATE II.

A—Surface features caused by the character of Conemaugh strata. The steep escarpment near the top of the hill is due to the resistance of the siliceous shales and shaly sandstones on the horizon of the Ames limestone which are underlain by the soft, clay-like shales of the Round Knob member. The Cow Run sandstone which outcrops about half way up the hill forms a prominent line of cliffs along the Muskingum Valley in southern Harrison and Bluerock townships.

B—"Bad land" areas caused by erosion and slumping of the clay shales along the horizon of the Cambridge limestone in southern Muskingum County.

The master preglacial stream of the area was the Newark River which is well described by Leverett as follows:[1]

Tight has shown that the greater part of the Muskingum drainage system was formerly connected with the Scioto system by a broad valley leading from Dresden (a few miles above Zanesville) westward past Newark to the Licking reservoir and thence into the Scioto Basin near Circleville. The present southward course past Zanesville is through a much narrower valley than the old line leading westward to the Scioto Basin, and the rock floor is markedly higher along the present course of the Muskingum than along the old course.

Along the old line of discharge there is, for about 10 miles, an open valley, 1 to 1½ miles in width, leading westward from Dresden past Frazeysburg. This open valley is now drained by a small stream, Wakatomika Creek, which enters it from the north near Frazeysburg. The old outlet of the Muskingum continues broad and open as far west as the eastern border of Licking County, where it becomes obstructed by a great accumulation of drift, which fills the valley to a height of 150 feet or more above the level of the broad bottom on the east. This drift filling obstructs the valley in this manner for only a couple of miles, and even there but half fills it, for the bluffs rise about 300 feet above the broad bottom first mentioned. At Hanover an open valley sets in, which extends westward to Newark and thence southwestward along the South Fork of Licking River to the vicinity of the Licking reservoir, where it is so filled with drift as to render its further course difficult to determine. A series of gas borings, however, indicate that it passes southward about to Hadley Junction and there turns westward, passing near Canal Winchester and Groveport and coming to the Scioto River about midway between Columbus and Circleville, where it seems to have joined the old Kanawha system.

The old line of discharge from the Muskingum into the Scioto Basin was excavated to a level much below the broad bottoms above described. A well about 1 mile east of Hanover is reported by Tight to have reached a depth of 218 feet without striking the old rock floor of the valley, though the bottom of the well is about 150 feet below the present level of the Muskingum at Dresden or about 550 feet above tide. It is 50 feet or more below the level of the rock floor of the present Muskingum at points 30 to 40 miles below Dresden. At Newark the old valley was cut to a level about 250 feet below the present river, or to less than 550 feet above tide. Gas wells at Hadley Junction and other points along the old line between Hadley and the Scioto River also reach a similarly low level before encountering rock.

In the Householder well, drilled 1 mile west of West Lafayette, 180 feet of sand and gravel were penetrated before bed rock was reached; in the Sharp well at Adams Mills 150 feet; in the Faucett well, 2 miles west of Trinway, 166 feet, and in the Frazier well, 2 miles west of Frazeysburg, 180 feet. In this old valley in the Black Run oil field the thickness of the filling is stated to vary from 87 to 227 feet. The greatest depth reported, 280 feet, is in the Herendeen No. 3 well, which is located just north of the village of Boston and 1½ miles east of the Hanover dam. These results show that the rock floor of this old waterway has an elevation varying from 570 feet to 600 feet above tide. The elevation of the rocks at Zanesville over which the Muskingum flows is far above this, as it is about 680 feet or nearly 100 feet higher. The results show that beyond question the Newark River was the master stream of the area.

[1]Leverett, Frank, U. S. Geol. Survey Mon. 41, pp. 155–156.

Concerning the present line of discharge Leverett says:[1]

Turning now to the present course of the Muskingum below Dresden, we find a much narrower valley than the old channel of discharge, the width ranging between one-half and three-fourths of a mile in the first 25 miles below Dresden. It there grows narrower, and in the vicinity of the line of Muskingum and Morgan counties, 33 miles below Dresden, it is less than one-fourth of a mile in width and is bordered by abrupt bluffs 200 to 250 feet in height. This is the narrowest place on the lower course of the river and is apparently the site of an old divide. The valley, however, remains narrow nearly to the mouth of the stream, its measured breadth at Lowell, 12 miles above the mouth, being barely one-half mile.

No data concerning the elevation of the rock floor in the portion of the valley between Dresden and the supposed old divide have been obtained; but at Eaglesport, about 3 miles below the supposed divide, a gas well on the east side of the river about midway between the bluffs entered rock 30 to 35 feet below low water or about 615 feet above tide. Another boring at McConnellsville, 7 miles farther down the valley, is reported to have entered rock 50 feet below low water at that point, or 590 feet above tide. The rock floor here seems to be about as low as at Lowell, 35 miles farther down the valley, the dam at Lowell being built upon the rock floor in the middle part of the valley which there stands at 580 to 590 feet above tide.

Concerning the height of the supposed divide above Eaglesport, there is good evidence from the contours of the bluff that it did not exceed 900 feet above tide, for the bluffs rise abruptly in this constricted portion to a height of only 875 to 900 feet. Possibly the old divide was even lower. In districts both to the east and west of the supposed divide on the Muskingum, cols are found at an altitude not far from 900 feet above tide, and this thus favors the view that the col crossed by the Muskingum stood equally low.

In the portion of the Muskingum Valley between Dresden and the supposed divide, glacial deposits, probably of Wisconsin age, have been built up to a level of 750 to 800 feet or more above tide, or about 100 feet above the present stream. They appear to be as high in Zanesville, at the mouth of the Licking River, as in the portion of the valley above, between Zanesville and Dresden. Below Zanesville the altitude apparently declines about as rapidly as the descent of the present stream, being by Locke level from the Government bench marks 85 feet above the river at Taylorsville, 90 feet at Eaglesport, 110 feet near the mouth of Meigs Creek, 119 feet at Beverly, and 105 feet at the mouth of the Muskingum. In the 75 miles from Zanesville to the mouth of the Muskingum the present stream descends from 683 to 570 feet above tide, while the gravel deposits descend from 800 feet to 675 feet above tide. Before this gravel was carried down the valley there apparently had been an excavation at the supposed divide to a level 30 to 35 feet below the present stream or to less than 625 feet above tide.

The terraces near the 780-foot contour in the Muskingum Valley from Dresden to the line between Muskingum and Morgan counties are largely composed of sand and gravel. Aside from the covering of soil the deposits in places are overlain by a few feet of fine sand which in local areas is mined for molding purposes, or by a few feet of light yellowish clay which represents another phase of the same unit. Thin lens-like layers of bluish clay are also occasionally encountered in the body of the sand and gravel. The material in these terrace deposits is distinctly stratified, cross-bedded, and well rounded. The

[1]Leverett, Frank, U. S. Geol. Survey Mon. 41, pp. 156–157.

largest sized pebbles in any considerable quantity are about the size of hen's eggs, although some much larger than this are occasionally present. The proportion of sand to gravel varies erratically both vertically and horizontally. At the plant of the Central Ohio Sand & Gravel Co., located about 1 mile south of Dresden, the general section is about as follows:

Soil	1 foot
Sand, fine silty, yellow, compact, used for molding purposes, average thickness	4½ feet
Sand and gravel, grayish to bluish, loose, used for concrete and other purposes	20 to 50 feet

At one place in these workings bed rock was reached at a depth of 20 feet, but elsewhere the valley floor was not found even though the pits were sunk to a depth of more than 50 feet. The bottoms of some of these pits are near if not below the level of the water in the Muskingum River at this place. At the pit of the Zanesville Washed Sand & Gravel Co., located about 2 miles south of Dresden, the general order of the rocks is the same as in that given above. The sand and gravel here is mined to a depth of 40 to 50 feet and the material is rather uniform when a long vertical or horizontal section is considered. Near Ellis and Gilbert the deposits also have great thickness, but the material is considerably finer than that at Dresden. Some thick lenses of nearly pure sand are present. At Philo the deposit is made up of 6 to 10 feet of coarse gravel, varying largely from pea to walnut size, underlain by 40 to 50 feet of sand and fine gravel in which few of the pebbles are above pea size. At this place the bottom of the pit is not far from the level of the water in the river which flows near bed rock. From these observations and others taken on both sides of the valley for many miles it appears that at one period the valley was filled from or nearly from the floor to an elevation of approximately 800 feet with the outwash material from the Wisconsin glacier. Parts of this were then gradually removed by erosion, whereas later deposits were gradually accumulating.

Regarding the extent of the old Muskingum drainage basin Leverett says:[1]

> The old Muskingum drainage basin extended up the Tuscarawas nearly to the mouth of One Leg Creek, a distance of 75 miles above the old westward outlet. The eastern tributaries of the Tuscarawas and Muskingum between the mouth of One Leg Creek and the south line of Muskingum County probably had as great an extent then as at present; but the northern and western tributaries of the Tuscarawas and Muskingum all appear to have been quite small. The Walhonding, which now has a drainage area of more than 2,000 square miles, appears to have formerly drained scarcely 500 square miles, its basin being mainly in Coshocton County. It received

[1]Leverett, Frank, U. S. Geol. Survey Mon. 41, pp. 158-160.

only the 8 miles of the lower course of Owl Creek below Millwood and the lower 8 or 10 miles of Mohican Creek. How much of Killbuck Creek was tributary to the Walhonding has not been determined, although it appears probable that the old divide was below the village of Killbuck or less than 20 miles from the mouth of the stream. Sugar Creek, which enters the Tuscarawas at Canal Dover, is almost entirely a new accession, the old divide being apparently south of Strasburg, only 6 or 7 miles from its mouth. From these observations it appears that the entire drainage area discharging westward past Dresden can scarcely have exceeded 3,000 square miles, which is but little more than half the area that now discharges southward past that point.

It has not been decided whether the old drainage of the portion of the Muskingum south of the westward outlet led northward from Zanesville along the present stream (reversed) to the old outlet at Dresden, or took a northwestward course from Zanesville, along a line followed in part by the Licking (in reverse direction), to enter the old outlet near Nashport. Along either line there is only a narrow valley scarcely one-half mile in average width. Drift accumulations in the northwestward line so conceal its channel that some uncertainty is felt as to its continuity, but it is the more direct line and appears to be fully as capacious as the northward line. In its favor there is also a peculiarity of drainage at Zanesville. An old valley leaves the present Muskingum just below Zanesville and bears northwestward through the western part of the city, being separated from the present river by a prominent ridge known as Putnam Hill. It there connects with the old channel leading up the Licking. It also connects eastward with the Muskingum, but this may be simply the old line of westward discharge for a small drainage basin north and east of Zanesville. In case there was an old divide on the present line of the Muskingum between Dresden and Zanesville it is more likely to have been near Ellis than at points above or below, as the valley is exceptionally narrow there. The bordering uplands also reach a higher elevation there than in other parts of this section of the Muskingum.

The portion of the westward outlet between Dresden and Newark apparently received the drainage from about the same territory as is now tributary to Wakatomika Creek and the lower course of Licking River. The headwater portions of the North Fork and the Middle or Raccoon Fork of Licking River appear to have discharged directly westward into the Scioto Basin, as determined by Tight, there being an old divide crossed by the Raccoon Fork near Granville, and by the North Fork south of Utica. The South Fork of Licking once received a larger drainage from the east than it does at present. Jonathan Creek, which now leads eastward into the Muskingum from near the Licking reservoir, crosses an old divide at the narrows in its lower course near Fultonham, as determined by Tight and Davis. The greater part of the old drainage was in the reverse direction from the present stream and entered the old outlet near the Licking reservoir. Farther south the old outlet received the headwater portion of the Hocking River from as far down as Rockbridge, in northern Hocking County, including the entire drainage basin of Rush Creek. It also received the drainage of the district now tributary to Little Walnut Creek, a portion of the outlet now being followed by the creek.

Carney[1] considers that much of the rock sculpturing, usually attributed to inter- or post-glacial development, of the Licking River and of the gaps between it and the old Newark River between Nashport and Hanover antedate the formation of the Hanover dam. Mather[2] also holds this view in regard to the Black Hand Narrows. Further, Carney states that a lobe of the ice sheet extended eastward across the low gap

[1]Carney, Frank, Bull. Sci. Lab., Denison University, Vol. XIII, 1907.

[2]Mather, Kirtley F., Bull. Sci. Lab., Denison University, Vol. XIV, 1909.

south of Black Run or for about a mile into Muskingum County. As the works of these writers have reference more to the area in Licking County they will not be reviewed here.

Puzzling stream modifications are also present from Irville to Shannon, along the headwaters of Big Run and Bartlett Run, and from the headwaters of Joes Run southward to Zanesville and eastward to the Muskingum River. Old drainage lines are apparent in these wide and in places basin-like valleys, but their directions have not been determined. Another abandoned valley is followed by the Wheeling & Lake Erie Railroad past Drake in southeastern Muskingum and northeastern Falls townships. Kent Run, rising near Mount Sterling, and emptying into Jonathan Creek at White Cottage, shows extensive modifications. It appears to have captured the headwaters of both Painter and Valley runs, two small streams flowing southwestward to Jonathan Creek. Salt Creek which rises in western Highland Township and unites with the Muskingum River near Duncan Falls shows similar but somewhat more complex modifications.

The Illinoian Drift Sheet

Only one of the great drift sheets that so largely covers northern and western Ohio lies in Muskingum County. This sheet is considered by Leverett the Illinoian and is taken to have been deposited by the third great body of ice that advanced southward from the Canadian highlands into the United States. It was influential in modifying topography not only by the direct action of the ice itself, but by the work of its released waters and by the deposition of its mineral debris. The terminus of the Illinoian ice sheet is seldom conspicuously marked by thick accumulations of drift in the form of ridges and knolls. On the summits of the hills the covering is generally thin and in places it consists only of scattered bowlders. However, along the valleys and ravines at or within the border, the glacial material is usually many feet in thickness. Its most marked effect is in the modification of drainage lines.

The line of the Illinoian drift in Muskingum County, which was carefully mapped by Prof. Thomas M. Hills is as follows: It enters the county in the southeastern corner of Section 16, Hopewell Township, extends east of north to Wesley Chapel in Section 15, thence northwestward to the central part of Section 9, and thence along Kent Run to Section 4. From this place the line is west of north to the National Road, 1 mile west of Coaldale, and thence along the same course to the western part of Section 15, north, where it passes into Licking County. Carney[1] has shown that a lobe of the Illinoian sheet also extended

[1]Carney, Frank, Bull. Sci. Lab., Denison University, Vol. XIII.

for about 1 mile into Muskingum County along the old Newark Valley in the northwestern part of Licking Township.

In the small glaciated area of Muskingum County the Illinoian till consists largely of plastic blue clay and fine-grained sand. Near the surface these are usually oxidized to a yellow or buff color and are firmly compacted. The till contains many fragments of flint which were evidently derived from the Upper Mercer and Ferriferous members in the immediate vicinity, and some gravel and bowlders which are of igneous or metamorphic origin and therefore from foreign sources. The granite and quartzite bowlders are usually small, but a few were observed more than 1 foot in diameter. The proportion of coarse material to fine is very low. Only in places where streams had sorted the material were glacial beds observed. In the old Newark Valley the filling from the Illinoian ice sheet according to well records is largely silt and sand with but little coarse material. The granite bowlders evidently of Illinoian age found along the ridges are not conspicuously decayed; in fact, they appear nearly as fresh as those of the later Wisconsin drift sheets. Aside from the till and outwash material of the Illinoian ice sheet, deposits apparently related to glaciation and consisting of silty, ferruginous, fine-grained sands are present on many of the ridges and hills both within and without the border of the drift.

Wisconsin Glacial Stage

The last great glacial stage recognized in Ohio is the Wisconsin. It did not enter Muskingum County, but extended as far east as Newark in Licking County and therefore had an indirect influence. The water from the melting ice sheet poured down the drainage lines which were thus considerably modified. In places the valley walls were severely eroded, whereas in other parts the channels were being filled with great loads of transported material. The deposition of outwash glacial matter began as soon as the moving ice reached the rims of the drainage basins and lasted through its advance down these basins and through its retreat back to the drainage divide. The Muskingum River thus received material from streams heading within the glaciated area, the most important of which are Licking River, Walhonding River, Killbuck Creek, and Tuscarawas River. The gravel and sand in the main terrace along the Muskingum and Licking rivers in Muskingum County thus appear to be largely outwash from the Wisconsin drift sheet. These deposits, now of considerable economic importance, are discussed by Dr. J. A. Bownocker in the chapter on Sand and Gravel.

CHAPTER II

MISSISSIPPIAN AND POTTSVILLE FORMATIONS

STRATIGRAPHIC AND ECONOMIC FEATURES

General Statement

All the consolidated rocks which appear at the surface in Muskingum County are of sedimentary origin, and were deposited either by or in water. They consist of sandstones, conglomerates, shales, clays, coals, limestones, iron ores, and flints. The coal beds vary greatly. Some have remarkable persistency and retain their thickness, structure, and composition for long distances; whereas other deposits suddenly disappear or change. The flints are of interest for their connection with the State's early history as well as for their origin and stratigraphy.

The consolidated surface rocks in Muskingum County belong, in the main, to the Pennsylvanian system, which here has a thickness of approximately 1,070 feet. The upper formations of the Mississippian system and the lower formation of the Dunkard system are also represented, and the Pleistocene and Recent deposits of the Quaternary are found along the present and abandoned water courses.

Along the valleys of the main streams are found thick beds of loosely cemented and interstratified sand, gravel, and clay, known to be of glacial origin from their mineral composition and physical character. These deposits were evidently laid down by the waters from the great ice sheet, as its terminal margin was close to the western boundary of the county. Other interesting strata, although small in extent, are the eolian deposits of sands and clays found near the summits of the hills and worked for metallurgical and ceramic uses.

Dip of Strata

In Muskingum County the rocks have a general dip both to the east and to the south, the dip eastward, however, being approximately three times as great as the dip southward.

Dip to the East.—In the northern part of the county the dip of the rocks to the east which is fairly uniform is about 21 feet per mile. This measurement was made, using the Middle Kittanning coal as a basis, from Section 5, Cass Township, to Maysville or Marquand Mill in Section 5, Monroe Township. At this place there is a pronounced flexure of the strata as the rise of the rocks to the east is nearly 24 feet

to the mile from Marquand Mill to White Eyes Creek, Section 1, Monroe Township.

A syncline is very pronounced at Marquand Mill, its low part, and it was traced southward across Monroe and Highland townships into Union Township where it is found just west of New Concord. Thence it extends with the same general trend across eastern Union Township into Rich Hill Township where it passes into Guernsey County on Mays Fork in Section 36. This syncline also extends northward from Marquand Mill in Monroe Township across Franklin and Tuscarawas townships, Coshocton County, to Coshocton. The general trend of the anticline is from the gas field west of West Lafayette, Coshocton County, through Linton Township, Coshocton County, and Monroe Township, Muskingum County, to the eastern part of Section 10, Highland Township, where it passes into Guernsey County.

The dip of the rocks across the middle of the county from Wise School, about 2 miles northwest of Mt. Sterling, to where the Middle Kittanning coal passes below drainage along the Baltimore & Ohio Railroad north of Zanesville, is almost uniformly 23 feet per mile. East of this the dip measured by the Anderson coal is much the same until the syncline west of New Concord is reached. From Section 23, Newton Township, to Duncan Falls, and also, across Salt Creek Township, the general dip of the strata to the east is approximately 24 feet to the mile and is fairly uniform. In the southeastern part of Union Township and in the northeastern part of Rich Hill Township the Pittsburgh coal rises to the east at a rate of about 14 feet per mile. The dip to the east across the southern parts of Clay, Brush Creek, and Harrison townships is about normal, or 22 feet to the mile. Across southern Bluerock Township the inclination is more rapid, being about 31 feet per mile. In Meigs Township to the east, the dip is only about 15 feet per mile.

Dip to the South.—In the western part of Muskingum County, measured by the Lower Mercer limestone for a distance of 22 miles from Section 14, Jackson Township, to Section 3, Clay Township, Perry County, the inclination of the strata to the south is 7.3 feet per mile. In the middle of the county, the normal dip of the rocks, measured by the Middle Kittanning coal from the northwest corner of Adams Township to Duncan Falls, is about 10.2 feet to the mile; and the dip from Duncan Falls to the Muskingum-Morgan county line is nearly 16 feet per mile. To the south across the eastern part of the county the average dip of the rocks is approximately 12 feet per mile, but the dip is not constant owing to the folding of the strata in this area. From Section 21, Monroe Township, to near New Concord, the inclination to the south is approximately 23 feet per mile, but from Section 12, Union Township, to Section 16, Meigs Township, it is only about 4.5 feet. The figures given do not indicate the maximum extent of the

dip either to the east or south where short distances only are considered. The strike of the rocks in Muskingum County, west of the syncline which lies in the eastern part, is 23° 23′ east of north. The general maximum dip at right angles to this or 23° 23′ south of east is 24.7 feet per mile.

MISSISSIPPIAN SYSTEM

Rocks belonging to the Mississippian system appear above drainage in the western tier of townships in Muskingum County, the greatest thickness observed being in western Jackson and Licking townships, where about 100 feet of sandstone and shale are exposed. In Hopewell and Newton townships the system is represented by a thick deposit of limestone, although beds of shale and sandstone are also present. Only two formations belonging to the Mississippian system, the Logan and the Maxville, appear above drainage in this county.

LOGAN FORMATION

Stratigraphy and Value

The rocks of the Logan formation are primarily sandstones and shales with occasional thin beds of iron ore and are about 175 feet in thickness. The sandstones are in general more or less irregularly bedded and are somewhat interstratified with shales. Where unweathered, they are usually light or bluish-gray, but where exposed, they are brown or yellow. The Logan shales on the average are very siliceous, differing in this respect from the shales of the overlying coal formations. They are coarser grained than most shales and where unweathered are gray or bluish-gray. The elements reduce them very rapidly to plastic masses. These beds often pass both horizontally and vertically into shaly sandstone. Concretionary masses and thin beds of siliceous iron ores are found irregularly distributed throughout the formation. The following section taken along the road north of Black Run, Section 25, Jackson Township, shows the usual character of the upper Logan deposits:

	Ft.
Shale, gray, siliceous	10
Sandstone with shale interstratified	6
Sandstone, shaly, gray	44

At other places the proportion of shale to sandstone is much greater than it is where the above section was taken. In local areas the upper 20 or 30 feet of the Logan formation is made up of thin to medium bedded sandstone with interstratified shales.

The Logan shales have some economic value as they are used in ceramic products, being well fitted for building and paving brick. At maturity, which occurs at a somewhat high temperature, they burn to a hard vitrified body with a pleasing red color, and there is little loss of ware from deformation. The total shrinkage of the body is

about $1\frac{1}{4}$ inches per foot. The Logan sandstones have very little value as they are too soft for building stone and as they have unattractive colors. On the whole the Logan formation adds but little to the mineral wealth of Muskingum County.

MAXVILLE LIMESTONE

Surface deposits of the Maxville limestone in Muskingum County are confined to Newton, Hopewell, and Falls townships, although the horizon is well above drainage in Licking and Jackson townships. Drill records show an extension of the formation into Brush Creek Township, but these records do not clearly define the boundary of the field. The Maxville is the upper formation of the Mississippian system.

Stratigraphy and Extent

Morse has shown[1] that the deposits of Maxville limestone in Muskingum County and in central and southern Ohio are only remnants of what was at first a continuous deposit, but which was later separated into patches by erosion before the deposition of the Pottsville rocks. Many exposures show the thinning of the deposits to result from the erosion of the upper layers. The irregularity of the upper surface of the deposits is also marked and a well-defined disconformity is apparent. This disconformity, however, is better illustrated when the rocks of a wide area are plotted with reference to some definite datum, for the fact is then seen that in the area in which the Maxville is wanting the Pottsville rocks often extend far below the horizon of the Maxville. In other words, the Maxville deposits appear as islands surrounded by a sea of Pottsville rocks.

The lower contact of the Maxville limestone is not shown at nearly so many places as is the upper one, but wherever exposed it furnishes an interesting problem for study. Since the lower part of the limestone is decidedly argillaceous in Cuts No. 3 and 4 (Section 14, Newton Township, Muskingum County, and Section 15, Madison Township, Perry County), and since there is seemingly no break between this impure limestone on the one hand and the sandstones and shales of the Logan on the other, the line of contact has to be somewhat arbitrarily drawn.[2] It seems probable that the clay and fine sand which were derived from the Logan were more or less worked over and into the basal layers of the Maxville. At Opera Bridge on Kent Run, the line of contact is much sharper and is slightly wavy. The upper surface of the subjacent shales is decidedly uneven in the Jockey Hollow exposures, and furthermore the joints in the upper part of these shales are filled with the same kind of material as that which forms the coarse arenaceous limestone of the basal layer of the Maxville. At the last

[1]Morse, W. C., The Maxville limestone: Geol. Survey of Ohio, 4th Ser. Bull. 13.
[2]Plate III.

place, then, it is quite obvious that the uneven surface upon which the Maxville rests represents at least a plain of contemporaneous erosion, and when the lower layers of the limestone are studied it seems more than probable that the structure is a disconformity.

A thin zone in the basal portion of the Maxville at Jockey Hollow and near Redington, in the Northern Area, and more or less of the entire formation at Hamden (and certain zones at Limeville) in the Southern Area, are decidedly brecciated. Many of the angular pieces are limestone, much purer, harder and darker than the coarse, sandy material which constitutes the mass of the breccia, and, for that matter, darker than any of the Maxville. The origin of these angular limestone pieces could not have been distant, or they would have become rounded in transportation, and if near, then Ohio must have had a Mississippian limestone other than and older than the Maxville, of which they alone are the representatives.[1]

The Maxville deposits are made up of thin to massive beds of limestone separated by layers of shale which vary in thickness from less than an eighth of an inch to more than 1 foot. The lower layers of limestone are at many places rather thin, widely spaced, and somewhat siliceous, and at a few places the upper layers have the same general characteristics. The main body of the deposit, however, is made up of limestone beds separated only by wavy mud layers or by very thin beds of shale.

The Maxville formation as a whole is sparingly fossiliferous. Fossils are more plentiful, however, along a few zones in the limestone and in some layers of the interbedded shales. The best of these are along Kent Run near White Cottage, and along the Zanesville & Western Railway from Fultonham to Mt. Perry.

Newton Township.—In Muskingum County the Maxville limestone has its greatest development in Newton Township where the beds extend in nearly an unbroken sheet along Jonathan Creek from the central part of Section 9 to the western part of Section 14 and along Kent Run from White Cottage to the western part of Section 2. Oil well records also show the extension of the deposits eastward and southward under heavy cover. The maximum thickness of this limestone is in the vicinity of White Cottage and Fultonham where from 30 to as much as 60 feet are reported. The upper layers are less siliceous and magnesian than the lower layers. In this township the top of the Maxville limestone is usually between 75 and 90 feet below the Lower Mercer limestone and only a few feet below the Quakertown or No. 2 coal.

The full thickness of the Maxville limestone is not exposed for measurement along Jonathan Creek or along Kent Run except near the western part of the township, as these streams are bedded in this limestone is usually between 75 and 90 feet below the Lower Mercer mile below the mouth of Buckeye Fork follows:[2]

[1]Morse, W. C., Geol. Survey of Ohio, 4th Ser. Bull. 13, p. 101.

[2]Morse, W. C., Geol. Survey of Ohio, 4th Ser. Bull. 13, pp. 53-54.

Maxville limestone.	Ft.	In.
Thin-bedded, gray, fossiliferous limestone to top of exposure in a ditch	1	10
Interval practically all covered	1	9
Thin-bedded, gray, fossiliferous limestone	2	7
Layer of compact, gray limestone forming the top of bank	--	9
Parting	--	4
Layer of compact gray limestone	--	10
Two layers of compact gray limestone with shaly and nodular partings	1	3
Layer of compact gray limestone which may separate into two	1	6
Two thin layers of gray limestone with thin partings	--	9
Layer of compact gray limestone	--	7
Shaly parting	--	1
Layer of compact, gray, fossiliferous limestone which may break into several layers	1	2
Shaly parting	--	1
Layer of compact gray limestone	--	11
Shaly parting	--	1
Layer of compact gray limestone	1	3
Shaly parting, wavy	--	5
Layer of compact gray limestone	1	5
Shaly zone, frequently with a layer of nodules at the center	--	6
Layer of compact gray limestone	--	6
Shaly parting, wavy	--	1
Thick layer of compact gray limestone, which contains calcite and some fossils	2	10
Shale—nodular zone. Nodular layers alternating with shale, to low water level	1	2

On the R. G. Thompson property near White Cottage the upper layers of this limestone exposed along Kent Run have the following measurements:[1]

	Ft.	In.
Layer of gray limestone	1	6
Layer of crystalline, fossiliferous, reddish limestone	1	9
Layer of fossiliferous, bluish-gray limestone	2	--
Layer of fossiliferous, cherty gray limestone	--	10
Layer of compact, fossiliferous, bluish-gray limestone	1	--
Layer of compact, reddish-gray limestone	--	3
Layer of fossiliferous, compact, bluish-gray limestone	1	--
Layer of compact, bluish-gray limestone	1	9
Layer of fossiliferous, hard, compact, crystalline limestone	1	4
Layer of fossiliferous, bluish limestone	--	6
Layer of bluish, slightly fossiliferous limestone, to water level	--	9

The sections given above show the general structure of the entire deposit of Maxville limestone exposed along Kent Run and Jonathan Creek.

On the whole the Maxville deposits of this area are very similar in structure and composition to those of southern Ohio and northern Kentucky.

Hopewell Township.—The main deposits of Maxville limestone

[1]Morse, W. C., Geol. Survey of Ohio, 4th Ser. Bull. 13, pp. 61-62.

exposed in Hopewell Township are confined to Poverty Run and its tributaries, although to the east local deposits are present also on two small streams that flow northward to the Licking River. The outcrop conditions indicate that the Poverty Run deposits are outliers from the main body of limestone in Newton Township and that large areas may be expected under cover in the central and southern parts of the township.

Along the small stream in the northeastern part of Hopewell Township an exposure of this limestone was found on the Monroe Smith property. The section follows:

Maxville limestone.	Ft.	In.
Limestone, hard, ferruginous	--	4
Limestone, siliceous	--	8
Shale, calcareous	--	2
Limestone, light-colored	--	10
Limestone, siliceous, ferruginous	1	--
Limestone, light-colored	--	3
Limestone, ferruginous	--	10
Limestone, siliceous	--	8
Sandstone	1	--

Another exposure farther down the stream shows the deposit about the same except that a thin sandstone is interbedded with the limestone. Near the mouth of the stream the Maxville is wanting. On the next small stream west of the above, and on the land of J Brown, the full thickness of this limestone is exposed and it measures only 6 feet.

The siliceous character of the lower layers prevails in this member throughout most of the township In the break between the Logan and Maxville rocks there is no gradation such as is seen at places in Newton Township. The upper 10 feet of the deposit is very pure.

In Section 12 a slight disconformity is indicated by the basal brecciated bed made up of gray siliceous limestone in which is imbedded light-colored angular pieces of limestone that resemble the true Maxville rock in character. These angular pieces show only slight rounding from transportation, but they do show some effect from solution. This layer suggests that it originated in shallow water near a shore line where a bed of limestone already formed was broken up by wave action and where the products now mixed with transported sands were recemented to a new rock. The siliceous character of the lower layers of the Maxville and the occasional interstratification of sandstone indicate land areas not far distant.

The Maxville limestone on the Frank Fink property on Poverty Run, is completely replaced by Pottsville rocks in less than 20 feet. The irregularity of the upper surface and the abrupt termination of the beds show the severity of the erosion that took place at the close of Mississippian time.

Along a tributary of Poverty Run on the property of C. A Brandon in the central part of Section 13, exposures of both Sharon conglomerate

and Maxville limestone were found. The massive and pebbly conglomerate lies a short distance down stream from the Maxville deposit and approximately 40 feet below it. With few exceptions the best developed deposits of Sharon conglomerate are found in the basins from which the Maxville limestone was removed. This condition is definitely illustrated not only in Muskingum County, but also in southern Ohio.

Falls Township.—The only deposit of Maxville limestone found north of the Licking River in Muskingum County is in northwestern Falls Township on the land of C. O. Marshall, which lies west of Sodom School. This deposit is local in extent. The section showing the relation also of strata higher in the geological column is given below:

	Ft.	In.
Pottsville formation.		
Limestone, *Putnam Hill*	4	--
Clay and covered	8	--
Covered	5	--
Sandstone, massive, soft	14	--
Flint, black, partially covered, *Upper Mercer*	2	--
Coal blossom, *Bedford*	1	--
Covered	54	--
Sandstone, massive	28	--
Covered	8	--
Sandstone, shaly	8	--
Shale and covered	4	--
Maxville.		
Ore	--	2
Limestone, dark, impure	--	8
Shale with nodules of limestone and ore	1	10
Limestone, light-colored	--	8
Limestone, light-colored	--	6
Shale	--	2
Limestone, yellow	1	6
Shale	2	6
Limestone, yellow, part covered	2	--
Logan formation.		
Sandstone, shaly, ripple-marked	17	--
Sandstone, very fossiliferous	--	4
Sandstone, shale, and covered	48	--

The thin ore bed and ferruginous nodules in the upper part of the Maxville appear to be limestones in which a part of the calcium carbonate has been replaced by iron oxides. This deposit is an outlier from the Poverty Run field and is about the same distance below the Mercer limestones as the Poverty Run, Kent Run, and Jonathan Creek deposits. Evidence of a basal disconformity is not marked at this place nor is there clear evidence of severe erosion of the upper surface.

In Licking and in Jackson townships no evidence of the Maxville limestone was observed although its horizon is above drainage. The same is true also north of this in Coshocton County as far as Warsaw. In this vicinity a brecciated layer of altered limestone, nodular ore,

and quartz pebbles, very similar to that so conspicuous in parts of Scioto and Pike counties, marks the contact of the Pennsylvanian and Mississippian rocks and represents a part of the products of the erosion between these periods. The brecciated layer at this place is from 1 to 5 feet in thickness and is overlain by the Sharon conglomerate which is pebbly and in places massive in character.

Economic Value

For many years the Maxville limestone has been used locally for building purposes. The stone is dense and hard and it has an attractive light-gray color. Owing to its brittle nature it is easily chipped to the desired forms. Like all limestones, it is affected somewhat by weathering agencies which change the color to yellowish or pinkish shades on account of the action of the elements on the included iron oxides. Many of the layers also contain imperfect bedding planes along which the blocks split when subjected to freezing and thawing. The layers best suited for building stone are those found in the upper half of the formation along Jonathan Creek in the vicinity of White Cottage and Fultonham. The layers of value are from 1 to 3 feet in thickness, rather uniformly bedded, and quite free from irregular mud layers. Care, however, should be exercised in the selection of material and the stone should be laid with the stratification planes horizontal to the original bedding. The solubility of the stone in acid ground waters appears to be low, as on the flood plains of the streams where this action is very severe the stone along the upper surface and joint planes of the deposits is decayed only a few inches. The apparent low solubility is probably due to the extreme density of the stone.

The proper criterion of quality of any material should be its durability in use. The Maxville limestone used in the construction of the court house at Zanesville in 1874 shows only slightly the effects of weathering. The stone, due to oxidation and soiling, is darker in color, but it shows no serious effects from solution or cracking. In the vicinity of its outcrop in Newton and Hopewell townships, this limestone has been used largely for foundations, road culverts, bridge abutments, retaining walls, and other minor uses. On the whole the Maxville limestone has a value worthy of consideration for local building purposes, although not sufficient to warrant its quarrying for the general market.

Road Metal, Ballast, and Concrete

The Maxville limestone has been used for road building in Muskingum County since the construction of the Maysville Pike 80 or 90 years ago. This long-continued use proves it very satisfactory for macadam roads.

Mr. A. S. Rea of the State Highway Department has kindly furnished the following report, which shows the general qualities of the Maxville and its value compared with other Ohio limestones:

Tests of Maxville Limestone

County	Quarry or farm	Abrasion	Cementing value	Slaking	Hardness	Sp. gr.	Wt. per cu. ft.	Absorption	Toughness
Muskingum	Zanesville & Western Ry.	6.6	24	OK	12.3	2.71	169	2.1	6.0
Muskingum	E. P. Grinsley	4.8	45	OK	17.0	2.70	168	0.3	6.5
Muskingum	R. G. Thompson	4.1	40	OK	17.9	2.70	168	0.4	7.5
Perry	J. A. Rose	4.7	29	OK	17.9	2.68	167	0.6	7.0
Perry	D. H. Hendricks	3.7	18	OK	15.3	2.68	167	1.8	6.7
Hocking	W. P. Myers	3.8	45	OK	18.1	2.73	170	0.9	9.0
Vinton	L. M. Kennedy	5.6	81	OK	17.0	2.63	164	0.8	6.5
	Average	4.8	40.3	----	16.5	----	----	----	7.0

Summary of Tests of Ohio Limestones

No. of tests	Formation	Abrasion per cent.	Hardness	Toughness	Cementing value
3	Redstone	5.5	14.3	6.7	42
1	Summerfield	4.9	17.4	7.0	102
1	Ames	5.0	17.0	6.0	63
13	Cambridge	4.6	17.3	6.6	93
5	Brush Creek	5.2	17.7	8.3	157
2	Flint Ridge	5.8	19.2	7.5	73
19	Vanport or Ferriferous	4.8	16.7	5.9	99
5	Putnam Hill	4.6	16.8	7.2	47
5	Mercer	6.7	15.8	6.7	49
7	Maxville	4.8	16.5	7.0	40
9	Delaware	5.6	14.7	6.7	53
28	Columbus	9.0	13.7	5.1	35
55	Monroe	5.0	16.1	7.2	66
15	Cedarville	10.7	13.7	5.4	27
4	Springfield	8.2	12.8	6.4	26
3	West Union	7.9	15.2	6.5	51
3	Dayton (Osgood)	7.0	14.8	6.2	68
13	Clinton	10.0	11.5	4.5	51
5	Richmond	5.8	15.3	5.8	59
3	Maysville (Lor.)	6.2	14.6	6.1	31
1	Point Pleasant	5.9	14.4	6.5	28
23	Mixed Samples	7.6	16.8	6.7	81
20	Niagara	8.7	14.4	5.3	38
16	Miscellaneous	5.8	16.4	7.5	85
259	Average	6.68	15.27	6.24	615

Mr. Rea also makes the following statement:

The Maxville limestone in general may be said to be above the average Ohio limestone as a road building rock. The unweathered stone shows a good resistance to wear in the standard abrasion test, good hardness, and fair toughness. When prepared to conform to requirements as to size, etc., this rock makes an excellent material for concrete and macadam roads:[1]

The value of limestone for railroad ballast is attested by the fact that it is fast replacing gravel and furnace slag. The advantages of the limestone are that it forms a solid bed which is able to withstand the strains of heavy loads; that it allows water to drain away, which increases the life of the ties, and that to a large extent it eliminates depressions where the rails are joined because it can be packed firmly. Moreover, the coarse stone gives little chance for unsightly grass and weeds which, because they hold moisture, promote rapid decay of the ties and rusting of the rails. Thus, for railroad ballast the Maxville is at least the equal of the average Ohio limestone, and is used with excellent results by the Zanesville & Western Railway.

For concrete work the stone should be clean, angular, and strong. A part of the dust or fine material developed in quarrying and crushing, especially if this is done in wet weather, sticks to or coats the rock fragments. This material prevents the cement crystals from securing firm attachment to the rock.

The Maxville limestone breaks into angular fragments with sharp edges and corners which give a good interlocking structure and provide centers of attachment for the cement crystals. The fracture produced in breaking is clean and not much dust is developed. During wet weather some of the shaly material from the partings and some of the clay from the overburden may become so mixed that it is necessary to wash the stone before use in concrete. Both the crushing and tensile strength of the stone make it suitable for engineering work and it has all the qualities required for concrete.

Lime

Near White Cottage and near Fultonham the Maxville limestone was formerly burned both for local use and shipment. It calcines readily, gives a good light-colored product, and owing to its high calcium content, it yields a hot lime. The limestone from the quarry of the Fultonham Stone Co. near White Cottage on calcination would yield a product with approximately the following composition:

Silica, SiO_2	5.61
Alumina, Al_2O_3	.86
Iron oxide, Fe_2O_3	1.93
Lime, CaO	90.88
Magnesia, MgO	.61
Phosphorus pentoxide, P_2O_5	.11
Total	100.00

[1]Personal letter, Jan., 1917.

Although this lime is considerably lower in quality than that produced from the dolomitic beds of northern and western Ohio, it is sufficiently pure for all ordinary purposes and, with the exception of the iron oxide which acts as a coloring pigment, the impurities are not detrimental. The quantity and quality of the Maxville limestone, the ease of calcination, and the proximity of the deposits to the coal fields favor the manufacture of lime, especially since the local demand for agricultural use is steadily increasing.

Portland Cement

The limestone found in the upper half of the Maxville deposit exposed in the vicinity of White Cottage and Fultonham is especially suited for the manufacture of Portland cement as the detrimental magnesia and sulphur are low. However, that in the lower half of the formation exposed along Poverty Run, Kent Run, and Jonathan Creek between Fultonham and Mt. Perry is not so well suited for cement as it is more magnesian in character. The following analyses show the quality of the stone:[1]

	Sample No. 1	Sample No 2
Silica, SiO_2	3.20	3.40
Alumina, Al_2O_3	.49	.70
Ferric oxide, Fe_2O_3	1.10	2.60
Lime, CaO	51.80	50.50
Magnesia, MgO	.35	2.20
Sulphur, S	.10	.11
Phosphorus, P	.027	.018
Titanic oxide, TiO_2	trace	trace

Sample No. 1, from quarry of the Fultonham Stone Co., near White Cottage.
Sample No. 2, from Norton Dove property on Poverty Run in Hopewell Township.

Ordinary shale from the coal formations has approximately the following composition:

Silica, SiO_2	58.20
Alumina, Al_2O_3	22.47
Ferric oxide, Fe_2O_3	5.63
Lime, CaO	.62
Magnesia, MgO	.98
Sodium oxide, Na_2O	.42
Potassium oxide, K_2O	3.08
Water, combined	6.15
Water, hydroscopic	2.45

By mixing this shale with the above limestones and clinkering the mixture, cements of about the following composition may be produced:

[1]Analyses made by Prof. D. J. Demorest.

	From sample No. 1	From sample No 2
Silica, SiO_2	23.80	21.08
Alumina, Al_2O_3	8.29	7.39
Ferric oxide, Fe_2O_3	3.26	4.84
Lime, CaO	62.50	62.50
Magnesia, MgO	.76	2.99
Sulphur, S	.12	.13
Phosphorus pentoxide, P_2O_5	.07	.05
Sodium oxide, Na_2O	.14	.12
Potassium oxide, K_2O	1.06	.90
	100.00	100.00

Cements of the above composition are well within the limits demanded by the trade. The limestone from the quarry of the Fultonham Stone Co. is superior to that from the Norton Dove property, as both the iron oxide and magnesia are considerably lower. The composition of both samples is such that addition of shale alone readily brings them to the proper cement ratio. The substitution of a coal formation clay for the shale, however, would yield lighter-colored products, as there is much less of the coloring pigment, iron oxide, in the clay than in the shale. Also it would decrease the alkali and increase the alumina contents.

Agricultural Lime

The increasing demand for agricultural lime calls special attention to the character of the local limestone deposits. Although a number of limestone members are present in the geological column in Muskingum County the soils in the western part are relatively low in calcium salt. These, however, are improved by applications of crushed or calcined limestone, and for this purpose the Maxville is well fitted as it is high in calcium. An analysis of the agricultural lime produced by the Fultonham Stone Co. follows:[1]

Silica, SiO_2	4.42
Alumina, Al_2O_3	1.16
Ferric oxide, Fe_2O_3	1.44
Sulphur, S	.10
Phosphorus, P	.025
Lime, CaO	50.70
Magnesia, MgO	.34

By converting these components into minerals the following results are obtained:

Marcasite, FeS_2	.19
Ferric oxide, Fe_2O_3	1.31
Calcium phosphate, $3CaO.P_2O_5$	.13
Clay, $Al_2O_3.2SiO_2.2H_2O$	2.93
Silica, SiO_2	3.06
Calcium carbonate, $CaCO_3$	90.41
Magnesium carbonate, $MgCO_3$	.71
Total determined	98.74

[1]Analysis by Prof. D. J. Demorest.

The analysis of the Maxville limestone quarried on Kent Run on the J. C. Stine property near Opera, and ground for agricultural purposes, is as follows:[1]

Calcium carbonate, $CaCO_3$	79.31
Magnesium carbonate, $MgCO_3$	9.19
Ferric oxide, Fe_2O_3	1.40
Alumina, Al_2O_3	1.90
Titanic oxide, TiO_2	trace
Phosphorus pentoxide, P_2O_5	.05
Sulphur, S	.29
Silica, SiO_2	6.59

The lower layers of the Maxville deposit along Kent Run are very siliceous in character. An analysis follows of an average sample of all the beds exposed there, and these have a total thickness of approximately 20 feet.

Calcium carbonate, $CaCO_3$	66.72
Magnesium carbonate, $MgCO_3$	4.57
Ferric oxide, Fe_2O_3	1.20
Alumina, Al_2O_3	2.03
Titanic oxide, TiO_2	trace
Phosphorus pentoxide, P_2O_5	.05
Sulphur, S	.32
Silica, SiO_2	23.24

The above analyses show that the upper part of the Maxville limestone, which is represented by the sample from the Fultonham Stone Co., yields on mill grind an agricultural "lime" containing 90 per cent or more calcium carbonate, which is the equal of the average northern or western Ohio product. However, the lower part of the Maxville deposit, represented by the limestone from Kent Run, is more siliceous and magnesian in character, but it is sufficiently pure to give excellent results. In the product from the Fultonham Stone Co. the proportion of calcium to magnesium carbonate is well balanced to meet the requirements of plant life; whereas in that from Kent Run the magnesium carbonate is somewhat high. Magnesium carbonate, however, is more effective in correcting soil acidity than calcium carbonate. The content of phosphoric acid, although small, should not be disregarded, for it is slowly available for plant food. The marcasite weathers to ferrous sulphate, which is also assimilated by plant life, whereas the free silica and clay remain as inert matter.

Owing to the great abundance of limestone in Ohio the markets for agricultural or "land lime" are somewhat local, but they should be best in the area south of the drift sheet and east of the outcrop of the Devonian limestone. Muskingum County is in this area and its soil

[1]Analysis by Prof. D. J. Demorest.

belongs mainly to the Dekalb series and was derived from the weathering of shales and sandstones.

The Fultonham Stone Co. prepares "land lime" for the general market from the Maxville limestone. The coarse grinding is done in a spindle crusher of the Gates type, and the fine reduction is accomplished by a ball mill. The product is uniformly fine and is guaranteed to contain 90 per cent calcium and magnesium carbonates. The plant is located on the Zanesville & Western Railway. Near Opera in Hopewell Township, this limestone is ground for the local country trade. The stone is quarried from the bed of Kent Run on the J. C. Stine property and is reduced by a Jeffrey disintegrator. The ground limestone which is guaranteed to contain 90 per cent carbonates is kept in storage.

Metallurgical Flux

The Maxville limestone may be employed for metallurgical flux, but it is much inferior to the best grades of Devonian and Silurian limestones of Ohio. The silica is above the standard usually demanded for basic hearth steel work, and the sulphur is also detrimental. For blast furnace work the available bases are what remain after the sulphur is eliminated as calcium sulphide and after the silica and alumina have been fluxed to slags by an equal amount of lime. On this basis the limestone from the quarry of the Fultonham Stone Co. contains 48.28 per cent available bases, which is somewhat low. For local furnace work in this county the additional cost of transportation of stone from central Ohio may overbalance the cost occasioned by the use of the native siliceous limestone, but on the whole the Maxville limestone in Muskingum County is not rated high for metallurgical use.

PENNSYLVANIAN SYSTEM

The Pennsylvanian system is the most important division of rocks in the eastern part of the United States as it contains many thick coal beds, which are the main dependence of vast metallurgical and other industrial operations, and which are also the principal source of domestic fuel. This system also contains thick deposits of clays and shales so largely used in the manufacture of refractory and building materials. The limestones and iron ores are of value, and the sandstones, where deeply buried by younger rocks, often act as storage reservoirs for the natural hydrocarbons, oil and gas. All the consolidated surface rocks of Muskingum County, except those in the extreme western part, belong to the Pennsylvanian system. Four formations, namely, the Pottsville, the Allegheny, the Conemaugh, and the Monongahela make up this system, and all, except the Monongahela, are represented in full thickness in the county.

KEY TO SECTIONS OF LOWER POTTSVILLE STRATA (Pl. III).

Section No. 1.—General section of Jackson County, Geol. Survey of Ohio, 4th Ser. Bull. 20, pp. 27-28.

Section No. 2.—Composite section near Till School, Section 1, Falls Township, Hocking County.

Section No. 3.—Taken one-third mile northwest of Maxville, Section 17, Monday Creek Township, Perry County.

Section No. 4.—Taken along the road in the western part of Section 35, Hopewell Township, Perry County.

Section No. 5.—Taken along the road in the northern part of Section 23, Hopewell Township, Perry County.

Section No. 6.—Taken along the road in the western part of Section 19, Franklin Township, Licking County.

Section No. 7.—Section up ravine in the northeastern part of Section 14, Newton Township, Muskingum County.

Section No. 8.—Composite section taken along the branch of Poverty Run 1½ miles north of Mt. Sterling, Hopewell Township, Muskingum County.

Section No. 9.—Taken along the road north of Poverty Run School in the northern part of Hopewell Township, Muskingum County.

Section No. 10.—Composite section taken along the road south of Claypool School, southwestern Licking Township, Muskingum County.

Section No. 11.—Composite section taken 2 miles southeast of Toboso, Hanover Township, Licking County.

Section No. 12.—Taken along the road 1 mile south of Toboso, Hanover Township, Licking County.

Section No. 13.—Taken along the road south of Irville, Licking Township, Muskingum County.

Section No. 14.—Taken along the road and in a ravine, Section 22, Jackson Township, Muskingum County.

Section No. 15.—Composite section on the farm of H. C. Johnson, Section 5, Cass Township, Muskingum County.

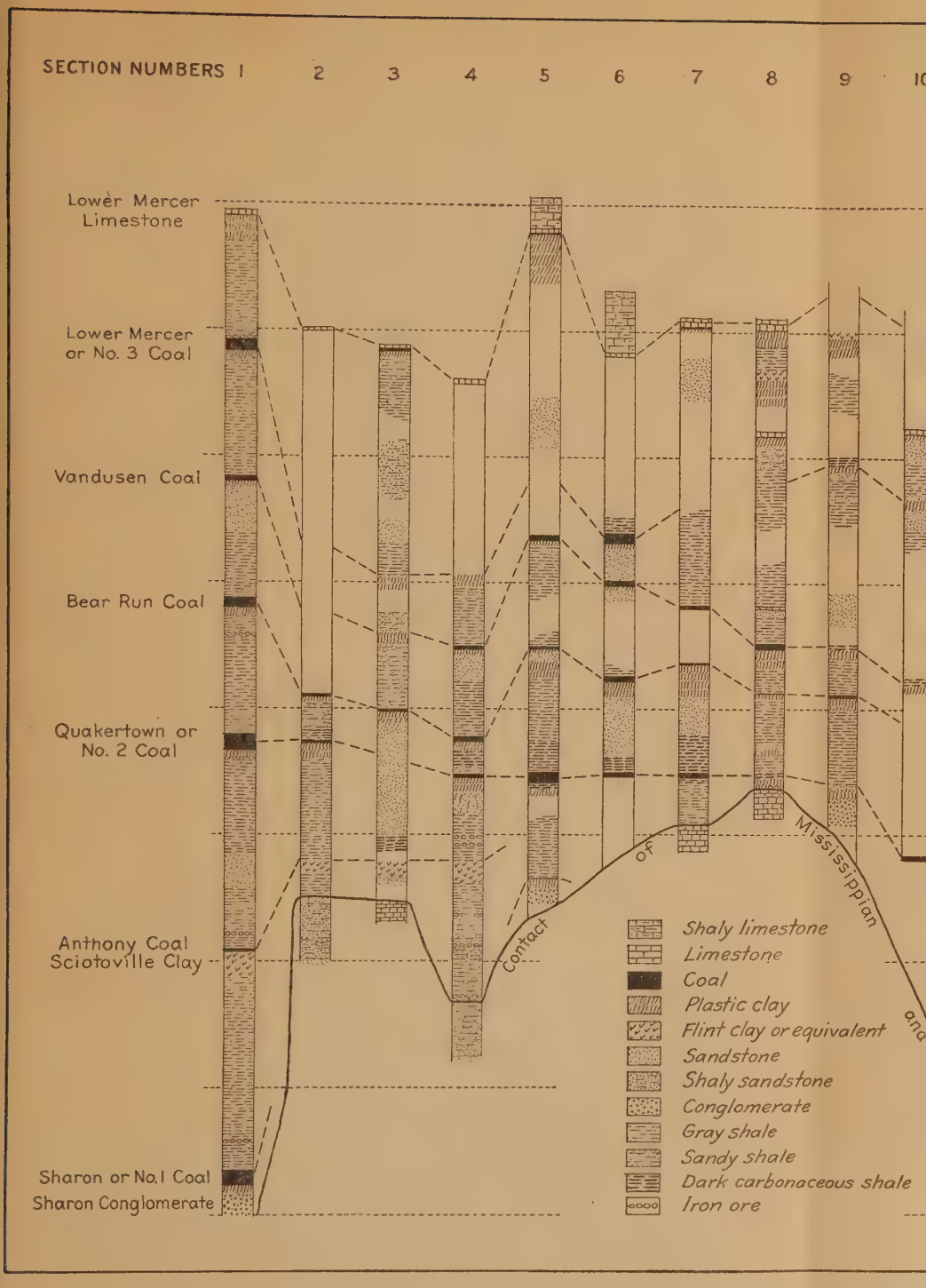
Section No. 16.—Taken along the road north of Black Run, Jackson Township, Muskingum County.

Section No. 17.—Taken on the land of Henry Norman, Section 8, Jackson Township, Muskingum County.

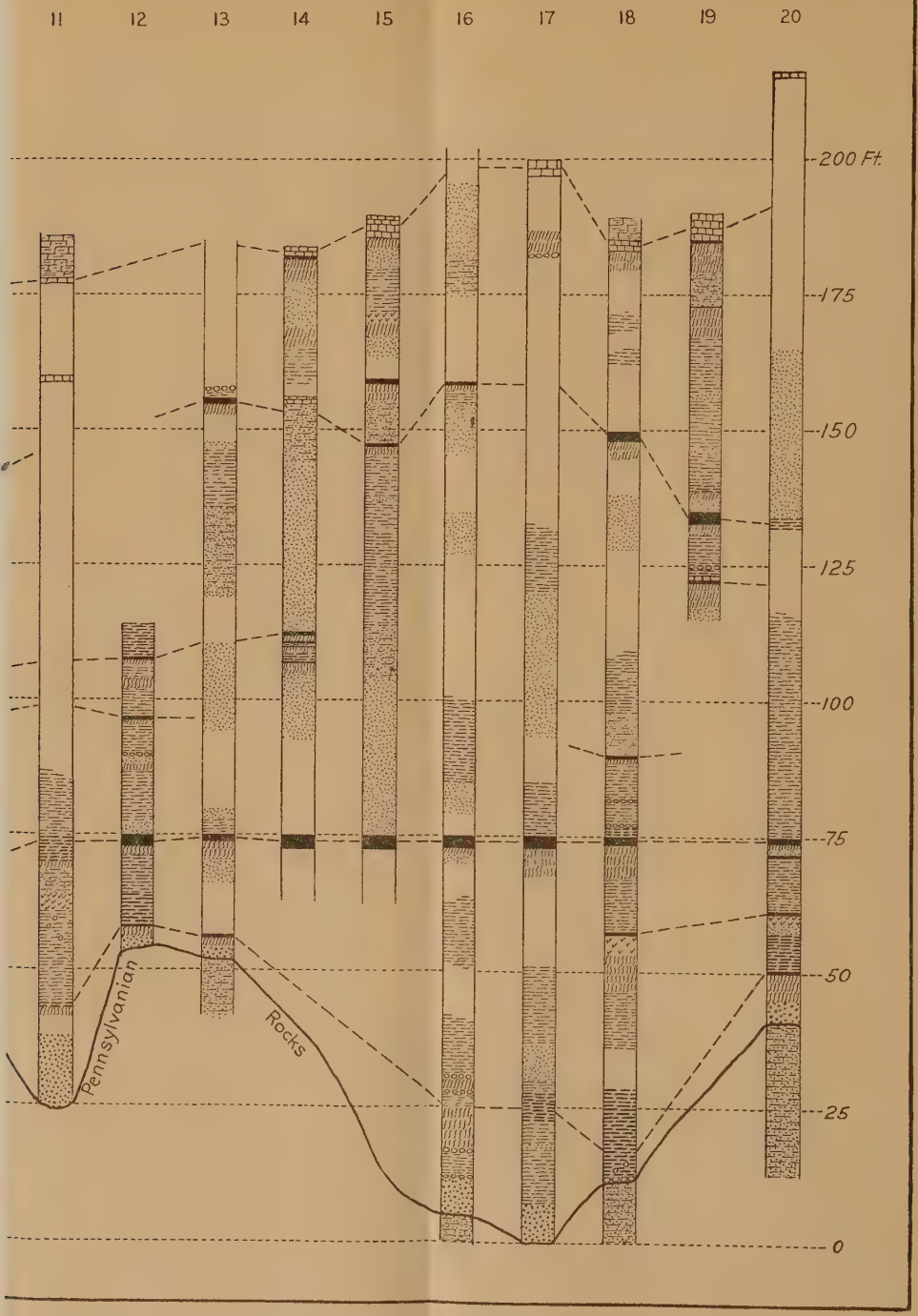
Section No. 18.—Taken along the road north of Fairview School, Section 7, Jackson Township, Muskingum County.

Section No. 19.—Taken in a ravine south of Graham Corners, Washington Township, Coshocton County.

Section No. 20.—Taken near the pumping station of the Pennsylvania Railroad west of Warsaw, Coshocton County.



Sections of Lower Pottsville Strata. Note the uneven contact



(unconformity) between the Pottsville and Mississippian.

The Pennsylvanian rocks rest unconformably on the Mississippian. The break in deposition represents a time interval of considerable duration during which not only crustal movements, but also extensive erosion took place. This disconformity is marked when a large area is studied and may be readily traced across the State. It has been noted in many places by Orton, Andrews, Morse, and others, and has been discussed in their reports to the Survey. The evidence indicates that at the close of the Mississippian epoch the crustal forces so elevated the rocks above the waters of the sea that severe erosion took place. This was followed by subsidence and then by the final deposition of the Pennsylvanian rocks. This pre-Pennsylvanian erosion not only removed the Maxville limestone from large areas, but it also cut deeply into the Logan sandstones and shales, leaving trough-like valleys or wide basins in which Pottsville deposits were laid down. Through this arrangement of the rocks the lower coal beds often appear stratigraphically to be below the Maxville limestone. In fact, they may be much below it in altitude.

POTTSVILLE FORMATION

The Pottsville, the oldest formation in the Pennsylvanian system, is exposed in full thickness in the western half of Muskingum County. Rocks of this age are found in Clay, Newton, Brush Creek, Springfield Hopewell, Wayne, Falls, Washington, Licking, Muskingum, Jackson, Cass, Jefferson, Madison, Adams, and Monroe townships. The areas, however, are small in some of the eastern townships. Many of the members, or minor divisions of the formation, especially those in the lower part, are poorly represented; whereas others are exceptionally well developed. The coal beds of the Pottsville formation are generally thin and economically unimportant, but its clays and shales are valuable. Although ranking low as mineral resources, its limestones are of considerable interest scientifically as they contain a profusion of fossils which delineate the marine life of those early coal formation seas and aid greatly in the correlation of strata. From the top of the Mississippian system, upon which, as previously shown, the Pottsville rests unconformably, the formation comprises all the rocks to the Brookville coal, which is the basal member of the Allegheny formation. The top of the Homewood sandstone, which lies below the Brookville coal, is often taken as the line of separation between the Pottsville and Allegheny formations, but this member is erratically deposited and is absent over large areas. There is no sharp line of demarcation between the two formations as the Pottsville rocks gradate imperceptibly into those of the Allegheny formation. Under these conditions the division is not based on lithologic evidence, but is largely arbitrary. Further, the fossil remains scarcely warrant a division of these formations as the fossils in the upper beds of the Pottsville are very similar

to those in the beds near the base of the Allegheny. The total thickness of the Pottsville formation, composed of coals, clays, shales, sandstones, conglomerates, limestones, cherts, and iron ores, is about 210 feet. The formation, where fully exposed, is thickest in the northwestern part of the county where the above measurements are exceeded at many places. The Pottsville formation is sub-divided into a number of members which will be considered in regular order, beginning with the oldest.

HARRISON ORE

The Harrison ore is noteworthy, not for its economic value, but for its relation to both the Pennsylvanian and Mississippian rocks, as it is deposited along the irregular zone of contact between these systems and as it contains in many places material from both. It lies in the Pottsville, but it is bedded on the eroded surface of the Maxville limestone or on that of the Logan strata. In places it is composed of a brecciated mass of siliceous fragments cemented by iron compounds. This siliceous material appears to be what was once pieces of Maxville limestone as it contains imperfect impressions of marine animal life, and it is usually present not far distant from Maxville areas. In general the pieces are quite angular, which suggests their origin from shore deposits by wave action, or from land areas by weathering agencies. These limestone fragments through solution lost their calcium and magnesium carbonates and by replacement gained additional silica. In other words such deposits are apparently the remains of deposits of Maxville limestone that were broken up by terrestrial and littoral forces, strewn over the eroded Mississippian plain by waves and currents, then covered by Pottsville sediments, and later cemented by iron compounds deposited from ground waters that circulated along this contact zone. This phase of the Harrison ore is not well exhibited in Muskingum County, but it may be found in counties to the north or south. At other places the Harrison ore is a mixture of angular siliceous fragments and of well-rounded quartz pebbles, the whole cemented by iron compounds. The pebbles are similar in every respect to those that compose the Sharon conglomerate which often lies directly above the ore. Deposits of this character are quite local in Muskingum County. In a few localities this ore is a rather pure ferrous carbonate or, where weathered, a hydrous ferric oxide. This is the condition usually when the bed lies directly on the Maxville limestone of which it appears to be a part. It is not, however, for where these beds have been cut by erosion the ore passes over both the limestone and shale layers alike. The general features of the Harrison ore are illustrated in the following section taken on land of Frank Fink in the southeastern part of Section 13, Hopewell Township:

	Ft.	In.
Pottsville formation.		
Shale, blue	3	--
Shale, dark, fissile	--	10
Clay, siliceous	1	10
Ore, siliceous	--	3
Shale *Harrison*	--	1
Ore, siliceous	--	3
Maxville limestone	0 to 6	--

In the above section the Harrison ore lies on the eroded surface of the Maxville limestone where this formation is present, and on the Logan shales where the Maxville is absent. In Section 4, north, Hopewell Township, on the property of W. E. Tewksbury, the following strata were exposed for measurement:

	Ft.	In.
Pottsville formation.		
Sandstone, massive	20	--
Shale and covered	15	--
Ore, *Harrison*	--	10
Logan formation.		
Shale	5	--

At this place the Harrison ore lies between shales, but is irregularly bedded. This is the usual condition of the member, where observed, in Licking and Jackson townships.

Northeast of Warsaw, in Coshocton County, the Harrison horizon is marked by local deposits consisting of siliceous limestone fragments and quartz pebbles, partially cemented by iron compounds. These deposits are very similar in every respect to those found in Jackson and Scioto counties.[1]

The Harrison ore at its best is low-grade, ranking below the Mercer deposits. It is usually siliceous in character, uncertain in extent, and variable in thickness. The iron is in the carbonate form unless weathered to the oxide state. This ore was worked to a small extent for the early forges and furnaces in the region, but is nowhere mined at present.

SHARON CONGLOMERATE

In Muskingum County the Sharon conglomerate is found in local areas in Newton, Hopewell, Falls, Licking, and Jackson townships. The member is seldom massively developed and is somewhat erratically distributed. As previously stated under the discussion of the disconformity between the Mississippian and Pennsylvanian systems, the Sharon conglomerate was laid down on the eroded and uneven floor of the Mississippian rocks, and is, in general, thickest in the low basin-like depressions. On the most elevated portions, and on the slopes of this plain, the deposits are generally thin and quite local. Lithologically the Sharon also varies greatly as it passes from the phase of a

[1]Geol. Survey of Ohio, 4th Ser., Bull. 20, pp. 28-29; 481-484.

No. 21, C. 1

light, argillaceous, fine-grained sandstone to that of a coarse, pebbly conglomerate. The pebbles are in the main the resistant mineral quartz derived from the igneous rocks. Vein quartz is the most probable source of the coarse material. The absence of other magmatic minerals is noteworthy as it indicates that many processes took place in order to eliminate all the other crystalline minerals, some of which are also very durable. The various processes of disintegration, transportation, and deposition were all involved, and the time interval from the first action of the forces on the granite rocks to the final deposition of the quartz pebbles as conglomerate was necessarily long. The two possible sources of such material were the old lands east of the Appalachian Mountains and the great Archean Plateau of Canada. The trend of the Sharon deposit and the relative quantities of such material in the two fields suggest that the quartz from which the thick beds of conglomerate originated came from the north or from the great Canadian granite fields. The Sharon conglomerate of Ohio is correlative with the Sharon of Pennsylvania and with the Olean of New York.

Newton Township.—Local deposits of Sharon conglomerate are exposed along Jonathan Creek and Kent Run in Newton Township. These deposits lie on the Maxville limestone and are seldom more than a few feet in thickness. In some places the Sharon is only a light-colored sandstone, whereas at other places it is characteristically pebbly. In order to show its relations to other members a record taken on Kent Run, in Section 1, west, is given:

Pottsville formation	Ft.	In.
Shale, dark	5	--
Clay shale, light, with iron ore nodules	1	4
Shale, dark	8	--
Sandstone, coarse-grained, *Sharon*	3	6
Ore, *Harrison*	--	4
Maxville limestone	1	--

West of this township in the vicinity of Mt. Perry, Glassrock, and Glenford, in Perry County, the Sharon conglomerate is massively developed and is characteristically pebbly. At Glassrock it is quarried and prepared for the trade.

Hopewell Township.—The Sharon member is above drainage in the southwestern part of Hopewell Township along Kent Run, and in the northern part along Poverty Run and the Licking River. It is not persistent and is seldom more than a light-colored, coarse-grained sandstone. However, in local areas it assumes the phase of a true conglomerate. The deposits bedded on the Maxville limestone are usually thinner than those lying on the Logan rocks. In order to show the various phases of the member and its relation to other beds, a few sections are given. The measurements obtained on the J. C. Fink property, in Section 12, follow:

	Ft.	In.
Pottsville formation.		
Sandstone, massive	19	--
Shale, dark	4	--
Conglomerate, argillaceous, *Sharon*	3	6
Maxville limestone.		
Limestone and shale	20	8

In this locality the conglomerate is composed of a mixture of pebbles and argillaceous matter, hence it is quite soft and weathers easily. The massive overlying sandstone is not a part of the Sharon as it lies above the horizon of the Quakertown coal. Along the road east of the Poverty Run School, the Sharon, bedded on the Logan strata, has good thickness, and is quite pebbly. Other sections taken in this locality show the same general features.

Falls Township.—The Sharon conglomerate in Falls Township is above drainage down the Licking River to Dillon Falls, and along Big Run to the township line. It is a coarse-grained sandstone, seldom conglomeratic, but usually cross-bedded. Although it is rather steady, only in local areas does it reach massive development. The following section taken on the M. A. Russel farm near the mouth of Big Run shows the general features of the member:

	Ft.	In.
Pottsville formation.		
Limestone, *Boggs*, flinty, dark, ferruginous	1	6
Covered	70	--
Shale	3	6
Sandstone, *Sharon*, coarse-grained	5	--
Logan formation.		
Sandstone, shaly	15	--

There are local deposits of Sharon conglomerate along the Licking River and along Big Run in the northwestern part of Falls Township. It is seldom a true conglomerate, being more often only a light, coarse-grained sandstone. It lies directly on Logan rocks.

Licking Township.—The Sharon member is above drainage in Licking Township along the valleys of the Licking River and its larger tributaries. It presents no few features except that it lies lower in the basin eroded in the Mississippian strata. The bed is generally thin and patchy and under such conditions the rock is more often a coarse-grained sandstone than a true conglomerate. Along the road south of Iryille the following beds were exposed:

	Ft.	In.
Pottsville formation.		
Shale and covered	3	--
Coal, bony, *Quakertown*	--	8
Clay, light, siliceous	3	4
Sandstone, light, shaly	5	--
Covered	9	6
Coal blossom, *Sharon*	--	6

Pottsville formation—Concluded.	Ft.	In.
Covered	2	--
Sandstone, *Sharon*, light, irregularly bedded	3	--
Logan formation.		
Sandstones and shales	30	--

Jackson Township.—The Sharon conglomerate is above drainage along the courses of the larger streams in all of Jackson Township, although in part of the area it is so covered that good exposures were observed at few places. The member is unsteady and is irregularly deposited on the Logan sandstones and shales. In some places it assumes the phase of a true conglomerate, whereas at other places it is only a light-colored argillaceous sandstone.

The following record, taken on the land of Henry Norman in Section 8, shows the Sharon conglomerate in good development and its relation to other beds of stratigraphic importance:

	Ft.	In.
Coal, *Quakertown*	1	10
Clay, light siliceous	2	--
Clay and covered	3	10
Covered	16	--
Shales, clay shales, and covered	14	--
Sandstone, irregularly bedded, coarse-grained, plant-marked	7	--
Shale, carbonaceous, with part covered	2	--
Shale, black, fissile, *Sharon* coal horizon?	5	--
Shale, gray, with part covered	5	--
Sandstone, hard, plant-marked	--	4
Shales, part argillaceous	10	8
Conglomerate, *Sharon*, upper 3 feet very pebbly	8	--

The Sharon member in this locality has marked development. The bed lies in a low part of the depression in the Mississippian rocks.

Economic Value

From an economic standpoint the Sharon conglomerate in Muskingum County deserves but little attention. In general the deposits are local in extent, variable in thickness, and changeable in composition. The member is seldom sufficiently weather resistant for a building stone and it is surpassed in quality by other more available coal formation sandstones. At no place in the county does it reach the standard of a high-grade glass sand owing to the content of iron oxide and clay matter. The percentage of pebbles is too small for its use in concrete, although the crushed material may be used for the sand ingredient where a light facing is desired.

SHARON OR NO. 1 COAL

The Sharon coal is not a conspicuous bed in Muskingum County. As previously stated, this member appears only in the low basins or depressions, cut by severe erosion, in the Mississippian rocks. The horizon is at few places marked by more than a few inches of bony coal or by a few feet of dark carbonaceous shale. The average normal

position of this member is only a foot or two above the Sharon conglomerate and about 40 feet below the Quakertown coal. Owing to the abnormal conditions of deposition, however, these intervals are subject to great variations. The horizon of the Sharon coal is above drainage in Newton, Hopewell, Licking, Falls, and Jackson townships.

Along Jonathan Creek and Kent Run in Newton Township, and along Poverty Run in Hopewell Township, the first definite coal bed above the Maxville limestone is the Quakertown. The Sharon coal is absent in these localities as deposition of Pottsville sediments began on the low parts of this Mississippian floor and not on the more elevated portions represented by these limestone areas. In parts of Licking Township, however, the coal appears. The intervals to the overlying Anthony and Quakertown coals, which usually are below normal, indicate a shoal water condition at the time of deposition. This spacing is shown in the following record taken along the road about 2 miles west of Nashport:

	Ft.	In.
Pottsville formation.		
Coal blossom, *Quakertown*	1	--
Clay, siliceous	3	6
Sandstone	2	--
Coal blossom, *Anthony*	--	6
Clay, light, siliceous, *Sciotoville*	4	--
Sandstone, shaly, light	2	--
Coal blossom, *Sharon*	--	6
Clay, very siliceous	2	--
Sandstone, shaly, light, *Sharon*	3	--
Logan formation.		
Shales and sandstones	10	--

The horizon of the Sharon coal is above drainage along the Licking River and along Big Run in the northwestern part of Falls Township, but no sections were obtained which would definitely locate the bed. Likewise in Jackson Township the member is so poorly developed that it is followed with difficulty. In the vicinity of Black Run and Frazeysburg the strata in the lower part of the Pottsville formation are largely shales and shaly sandstones in which siliceous clays and iron ores are interstratified. Only soot streaks of coal are present. North of this, along Wakatomika Creek, the horizon appears to be represented by black shales lying on or close to the Sharon conglomerate.

The Sharon coal in Muskingum County has no economic value as it is too thin or shaly to be mined even for local consumption. Moreover, the drill records secured do not indicate coal of any value at this horizon under heavy cover.

LOWER POTTSVILLE SHALES AND IRON ORES

Lying above the Sharon members, or above the base of the Pottsville formation, where these members are absent, and below the Quaker-

town coal, is a series of shales with interbedded sandstone, siliceous clays, and iron ores, which is best represented in Licking and Jackson townships. The total thickness of these beds varies from 10 to 70 feet. In general the shales in the thicker beds are siliceous, of coarse texture, and have a light-gray color. Lithologically they resemble very much the shales that overlie the Sharon coal in the Jackson County field. The ores belong to the kidney variety, they are very irregularly bedded, and are difficult to correlate from place to place. Such ores are also common in the lower Pottsville strata of southern Ohio. The ore beds vary in thickness approximately from 1 inch to 1 foot. Where unweathered, they are siliceous ferrous carbonates. The character of the strata from the base of the Pottsville formation to the Quakertown coal is shown in the following section taken along the road north of the village of Black Run in Section 25, Jackson Township:

	Ft.	In.
Pottsville formation.		
Sandstone, coarse-grained	6	--
Covered	4	--
Coal blossom, *Quakertown*	2	--
Clay shale	1	--
Sandstone	2	--
Covered	7	--
Shales and siliceous clays with parts covered	32	--
Ore, kidney	--	6
Clay, shale, light	2	6
Ore, kidney	--	6
Shale, ferruginous	2	6
Clay, light, very siliceous	7	6
Ore, kidney, siliceous, irregularly bedded	1	--
Shale, light, argillaceous	4	--
Ore, kidney, siliceous	--	6
Sandstone, light, argillaceous, *Sharon*	7	--
Logan formation.		
Shales and shaly sandstones	70	--

The kidney ores are present in this shale at many other places in Jackson Township, in some localities in Licking Township and they extend northward into Coshocton County.

The economic value of these beds is not great, although the shales and siliceous clays may be employed for the manufacture of ceramic products. The iron ores are usually siliceous and of little value, but were used to a small extent in the early furnaces in the region. Along the outcrop they are hydrated oxides, but under cover they are ferrous carbonates.

SCIOTOVILLE CLAY AND ANTHONY COAL

No true flint clay, such as is present in the Sciotoville field of Scioto County, was observed on the Sciotoville clay horizon in Muskingum County. In fact, the member is poorly marked even by siliceous clay or by the associated Anthony coal. Under

normal conditions, the position of these two members is about midway between the Sharon and Quakertown coals. The Sciotoville clay and Anthony coal are due above drainage in Newton, Hopewell, Licking, Falls, Jackson, and Cass townships.

Near Logan in Hocking County, the Sciotoville member lies only a few feet above the Logan rocks, and at Maxville, in Perry County, it is bedded on or close to the Maxville limestone. In both localities the deposits not only contain true flint clay and siliceous plastic clay, but also the mottled plastic clay usually known as "pink eye" in southern Ohio. In both the Logan and Maxville regions the Anthony member is commonly represented by a few inches of shaly coal. North of Maxville the clay member becomes more indefinite, but the horizon may be followed with some assurance across Perry into Licking County by scattered patches of mottled clay or clay shale. In many places both clay and coal appear to be absent.

Along Jonathan Creek and Kent Run in Newton Township, Muskingum County, are local deposits of siliceous plastic clay which is bedded on but near the edge of the Maxville limestone. This is assumed to be the eastward representative of the clay member. Neither flint nor mottled clay was observed. Similar conditions are found along Poverty Run in Hopewell Township. North of this in Licking Township, the lower Pottsville strata show more regularity and order, but the Sciotoville member consists only of siliceous plastic clay, and the Anthony bed of a thin layer of coal or carbonaceous shale. The following section, taken along the road in the southwestern part of the township, shows the general conditions observed:

	Ft.	In.
Pottsville formation.		
Shale and covered	10	--
Shale, black, *Quakertown* coal horizon	5	--
Clay, siliceous	1	--
Shale and shaly sandstone	5	--
Clay, upper part dark, *Sciotoville*	3	--
Shale with scattered ore nodules	7	--
Shale, gray	10	--
Shale, black, *Sharon* coal horizon	1	--
Clay, light, siliceous	5	--
Sandstone, light, coarse-grained, part covered, *Sharon*	3	--
Logan formation.		
Sandstone, shaly	12	--

Practically the same relations were observed in the vicinity of Irville and Nashport, but the coal beds are more prominent. But little may be added in regard to the Sciotoville clay and Anthony coal north of this in Jackson Township, as the clay, where present, retains its siliceous character, and the coal at many places is only a soot streak or a thin layer of dark shale. This clay and coal are above drainage, but are poorly developed in the western part of Cass Township.

In Muskingum County neither the Sciotoville clay nor the Anthony coal is of value. The clay deposits are uncertain and have no value as a refractory material. However, it may be used together with the associated shales for the manufacture of only the common grades of ceramic ware. The Anthony coal is too thin or too shaly to be mined even for local use by stripping along the stream beds.

QUAKERTOWN OR NO. 2 COAL

The Quakertown coal is the lowest member of real value in the Pottsville formation of Muskingum County. It is the third well-defined coal in the series, but is much more constant and better developed than either the Anthony or Sharon. The intervals separating the Quakertown coal from the Logan rocks or Maxville limestone are very changeable, expanding from a few feet to as much as 70 feet. This variation in intervals, however, is due largely to the unevenness of the Mississippian floor upon which the coal formation sediments were laid down. This coal lies above drainage in Newton, Hopewell, Falls, Licking, Jackson, and Cass townships, but in some of these localities the bed has little value.

Newton Township.—Along Jonathan Creek and along Kent Run in Newton Township, small pockets of Quakertown coal are found lying close to the upper surface of the Maxville limestone. In much of the area, however, the horizon is marked more by carbonaceous shales than by coal of value. The following record, taken along a ravine in the eastern part of Section 14, shows the relation of the Quakertown coal to the Maxville limestone.

		Ft.	In.
Coal, hard	*Quakertown*	1	--
Coal, shaly	*Quakertown*	--	4
Shale, hard, carbonaceous	*Quakertown*	--	7
Shale, sandstone and covered		8	5
Limestone, *Maxville*		8	--

Along Buckeye Fork east of Fultonham, the Quakertown coal lies close to the top of the Maxville limestone and has a thickness of about 8 inches. It is overlain by dark shales similar to those noted in the section just given. Where present along Kent Run the coal is thin or bony. West of Newton Township in Madison and Hopewell townships, Perry County, the Quakertown coal has fair volume locally and is mined in a small way.

Hopewell Township.—The Quakertown coal is generally thin, bony, or absent along Poverty Run and along the Licking River in Hopewell Township. It lies close to the underlying Maxville limestone or Logan rocks, and is usually associated with dark carbonaceous shale.

Licking Township.—The Quakertown coal is above drainage along the courses of all the larger streams in Licking Township, but

it is generally thin and often bony. On the land of Elizabeth Mercer, 1½ miles northwest of Pleasant Valley, this bed was formerly mined in a small way by drifting. The coal is reported to have a maximum thickness of about 3 feet. South of this on the adjoining farm of W. A. Mattingly the member is exposed in a stream bed where the following measurements were obtained:

		Ft.	In.
Sandstone, massive		15	--
Coal, cannel, bony	*Quakertown*	--	9
Shale, black, with thin coal bands		--	10
Shale, black, fissile		1	--
Sandstone and covered		13	--

The coal at this place appears to be near the edge of the field and to lie close to the Sharon conglomerate. The blossom of the Quakertown coal is exposed at other places in the southwestern part of the township. The most favorable exposures, however, indicate only about 1 foot 8 inches of coal, a part of which is often bony. In the northern part of the township this member is quite persistent, but is nowhere regularly worked at present. Formerly, however, the Quakertown coal was mined by drifting about 1 mile north of Nashport. The outcrop exposures indicate that the bed varies in thickness from a few inches to approximately 2 feet 6 inches.

Falls Township.—In this township the Quakertown coal is above drainage along the Licking River to Dillon Falls where small quantities of fuel are reported to have been obtained from the bed of the stream. The outcrop exposures indicate that the bed is generally thin, seldom exceeding 1 foot 6 inches in thickness. In places it appears to be represented only by highly carbonaceous shales. Nowhere in this township is the member regularly mined by drifting.

Jackson Township.—The Quakertown coal in Muskingum County is best developed in Jackson Township where it is mined in a small way for local use. The bed is quite steady, but in a few places it is replaced by the overlying sandstone. In a general way the thickness varies from 1 foot to 2 feet, but averages about 1 foot 10 inches.

Along the road in Section 25 north of the village of Black Run, a blossom of the Quakertown coal about 2 feet in thickness is exposed. In Section 22 on the property of G. Vickers the bed was regularly mined by drifting. The measurements obtained follow:

	Ft.	In.
Limestone, *Lower Mercer*	1	10
Coal blossom	--	6
Clay and sandstone	12	--
Clay and covered	3	--
Shales and covered	10	--
Flint, light, nodular, fossiliferous, *Boggs*	1	6
Sandstone, shaly and covered	11	6
Sandstone, massive, parts shaly	30	8

		Ft.	In.
Coal, bony		--	4
Clay shales, dark		--	10
Coal, bony		--	4
Shales, dark, with thin coal bands	*Vandusen*	--	6
Coal, bony		--	3
Clay shale, dark		1	1
Shale, black, with thin coal bands		1	10
Coal, bony		--	2
Clay, plastic, siliceous		2	--
Sandstone, massive, coarse-grained		12	--
Covered		18	--
Coal, *Quakertown*, reported thick ess for coal and partings		2	6
Clay		1	--

On this property several drift mines have been operated for local fuel. The roof of the coal is shale which is overlain by a massive sandstone. The interval from the coal to the Lower Mercer limestone is approximately 107 feet. North of Fairview School in Section 7 the Quakertown coal is exposed along the road. It measures 1 foot 4 inches in thickness and lies 108 feet below the Lower Mercer limestone. On the farm of Henry Norman in Section 8, the coal is mined by drifting.

About 2 miles north of Frazeysburg on the headwaters of a small tributary of Wakatomika Creek, the Quakertown coal has been mined for local use by drifting. The mines had all been abandoned when the region was visited in 1916, but the thickness of the coal is reported to average about 1 foot 8 inches. The member lies 120 feet below the Lower Mercer limestone at this place. Northeast of Frazeysburg the blossom of this coal was seen near the base of the hills, but it is generally thin or bony. No mines have been opened.

Cass Township.—The Quakertown coal is above drainage along the valley of Wakatomika Creek in western Cass Township, but as the covering is generally deep it is exposed for measurement at few places. It has been mined by drifting on the H. C. Johnson property in Section 15 only. The record obtained follows:

		Ft.	In.
Sandstone		5	--
Coal		--	8
Clay shale		--	1
Coal	*Quakertown*	1	1
Clay shale		--	3
Coal		--	5
Clay		1	--

Economic Value

The chief value of the Quakertown coal in Muskingum County is for local domestic use. In the area above drainage the bed is nowhere of sufficient thickness and purity to be mined in a large way. However, surface and mine measurements indicate that there are small

fields of a few square miles each in which the bed has an average thickness of 1 foot 6 inches or more. Counting 60 per cent available in mining this coal, where 1 foot 8 inches thick, will yield approximately 1,770 tons per acre. The general mining conditions for a thin bed are very good. In most of the area the roof material is shale which is solid and strong. In a few localities, however, this is replaced by a massive sandstone, which also forms a desirable covering, but which in local areas replaces a part or all of the coal stratum. "Draw slate" is found only along the border of the areas with sandstone covering. The floor of the coal is everywhere a siliceous clay which forms good footings for post and pillars. The clay has few qualities which recommend it for ceramic use, hence its value as an associated product of the coal is unimportant. The coal stratum is divided into benches by shale partings which vary in thickness from $\frac{1}{8}$ inch to 6 inches. These partings are somewhat detrimental as they add materially to the ash content of the fuel. The thickness of the bed is constant except where replaced in local areas by sandstone.

The coal is what is generally termed a block coal, as it mines in lumps or blocks because of the partings and joints. It belongs to the open or free-burning class. In local areas a part of the bed assumes the phase of cannel coal, but this is generally an impure, often dense, highly carbonaceous shale.

A sample of the Quakertown coal was taken by the writer from the mine of Henry Norman $1\frac{1}{2}$ miles north of Frazeysburg, in 1917, and was analyzed by Prof. D. J. Demorest. The sample was taken from under heavy cover where the coal was clean and bright and the thin parting was rejected. On account of the mine being wet and muddy the sample was somewhat moist.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	68.78	Moisture	9.80
Hydrogen	5.79	Volatile matter	35.12
Oxygen	16.87	Fixed carbon	49.10
Nitrogen	1.21	Ash	5.98
Sulphur	1.37		
Ash	5.98		

Calorific value { 6,745 calories. 12,142 B. t. u.

Air drying loss of moisture, 3.2 per cent.

Fusion temperature of ash { incipient, 1,125°C. complete, 1,460°C.

The high content of oxygen is due partially to the excess moisture. The ash and sulphur are moderately low and the heating value compares favorably with that of the average Pottsville or Allegheny coal of Ohio. The ash is clay-like and fuses only at high temperatures, thus causing

but little trouble from clinkering. The coal ignites readily and produces little soot.

MASSILLON SANDSTONE

A massive sandstone, which is the equivalent of the Massillon of Ohio, appears in the interval above the Quakertown coal in northwestern Muskingum County. It is especially prominent in Licking, Jackson, and western Cass townships where its outcrop is often marked by cliffs and escarpments. In Hopewell and Newton townships the deposits are generally thin and local. The stratum is very irregular in thickness and in structure. In some localities it occupies nearly all of the interval from the Quakertown coal to the Lower Mercer limestone, and in other places it is very thin and indistinct or even wanting. The deposit is usually divided into two parts, separated by shales, in which one or more thin coal beds appear. As a general thing, the Lower Massillon sandstone, or that part lying below the horizon of the Bear Run coal, is by far the most persistent and massive. The Upper Massillon sandstone lying between the Bear Run coal and the Lower Mercer limestone is usually patchy. They both replace coals, clays, limestones, and shales. The disconformity at the base of the Lower Massillon sandstone at many places is marked as it replaces many feet of other strata in a short distance.

The Massillon sandstone is rather coarse-grained and near the base is often somewhat conglomeratic. Because some beds are quite weather resistant they may be employed for building stone. In this county they have been used only for foundations, road culverts, cellar walls, chimneys, etc. This sandstone is seldom sufficiently pure for glass sand as the content of iron oxide and clay matter is too high. Some beds may be used, however, in the manufacture of low-grade ware such as bottles. Washing would improve the quality considerably, but not enough to justify the additional expense. On the whole the Massillon sandstone adds but little to the mineral wealth of Muskingum County.

BEAR RUN COAL

The next member worthy of consideration in the rock column of Muskingum County is the Bear Run coal. It lies approximately 74 feet below the Lower Mercer limestone and 29 feet above the Quakertown coal. The horizon is well marked across the county, but more by dark, carbonaceous shale than by coal, which is usually impure and seldom a foot in thickness. The associated clay is also of little value as in most places it is very siliceous and often broken by hard sandstone layers. The Bear Run coal is above cover in Newton, Hopewell, western Falls, Licking, Jackson, western Muskingum, and western Cass townships, but on account of its unimportance it will be traced only in a general way.

The Bear Run coal is thin or bony along Jonathan Creek and

A—Maxville limestone on Kent Run near White Cottage. Photo by W. C. Morse.

B—Massillon sandstone, highly cross bedded at Dillon Falls.

along Kent Run in Newton Township. In places siliceous clay more than coal marks the horizon. Practically the same condition is found along Poverty Run in Hopewell Township and along the Licking River in Hopewell and Falls townships. The coal is somewhat better developed in local areas in the southern part of Licking Township than in the townships to the south, but the thick Massillon sandstone generally replaces it in the northern part of Licking Township. The following measurements, taken on the farm of W. A. Mattingly, 1 mile west of Pleasant Valley, show the general position of the coal:

	Ft.	In.
Coal, cannel, bony, *Vandusen*	--	6
Shale, dark, hard	1	--
Covered	2	6
Sandstone, shaly	2	--
Shale, siliceous	2	--
Covered	3	--
Shale and covered	10	2
Shale with ore nodules	1	--
Coal, bright, hard, *Bear Run*	--	10
Sandstone, massive, conglomeratic	15	--
Coal, cannel, bony	--	9
Shale, black, with thin coal bands — *Quakertown*	--	10

Where the Bear Run coal does occur in Jackson, Muskingum, and Cass townships, the areas are small and the coal is broken and irregular. In this locality the Massillon sandstone generally replaces it.

The Bear Run coal in Muskingum County is of scarcely no economic value for, with few exceptions, the deposits are even too thin or bony to be mined by stripping along the stream beds, and the associated clay is very siliceous and unsteady.

VANDUSEN COAL

The Vandusen is the next coal bed in ascending order in Muskingum County. The average position of this coal is 58 feet below the Lower Mercer limestone. This coal, like the underlying Pottsville coals, is uncertain in extent and volume, but where it is absent the horizon is usually marked by beds of carbonaceous shale, so that it may be followed with some certainty across the county. The Vandusen coal is above drainage in Newton, Hopewell, Falls, Licking, Jackson, Muskingum, Cass, Jefferson, and Madison townships.

Newton Township.—The Vandusen coal is above drainage along Jonathan Creek, Kent Run, and their tributaries, but the bed is generally thin, bony, or absent. The horizon is more often marked by deposits of black shale or siliceous clay than by a well-defined coal stratum. No coal of sufficient thickness even for stripping was observed.

Hopewell Township.—The Vandusen coal is present above drainage in Hopewell Township along Kent Run in the southern part, and

along Poverty Run and the Licking River in the northern part. At no place has it been mined except by stripping in stream beds or along the outcrop where the cover is shallow. Its relation to other members is shown in the following section taken on land of Della Wise and others, located about 1 mile northwest of Mt. Sterling:

	Ft.	In.
Coal, *Vandusen*	--	10
Clay, light, siliceous	3	8
Shale, argillaceous	2	--
Shale, blue	3	--
Shale with thin coal bands, *Bear Run*	--	3
Sandstone, hard, plant-marked	--	3
Clay shale, light-gray	3	--
Shale, siliceous, blue	4	--
Shale, gray	3	--
Sandstone, ferruginous, conglomeratic	--	6
Clay shale	2	--
Shale, blue	3	--
Shale, dark, fissile } *Quakertown*	--	8
Shale, black, bony } *Quakertown*	--	2
Clay, siliceous	1	10
Ore, siliceous } *Harrison*	--	3
Shale } *Harrison*	--	1
Ore, siliceous } *Harrison*	--	3
Limestone, *Maxville*	6	--

East of Poverty Run School on land of F. H. Fairbanks, a small quantity of coal has been taken from this bed by stripping, and the coal measures 1 foot 2 inches. It lies only 28 feet above the top of the Maxville limestone which is fairly well developed. Both coal and black carbonaceous shales are exposed on this horizon at many other places in Hopewell Township, but they will not be considered further.

Falls Township.—In Falls Township the horizon of the Vandusen coal is more often represented by carbonaceous shales than by coal of any noteworthy thickness. In some places, however, there are from 6 inches to 1 foot. On land of E. G. Marshall, north of the Licking River, and about 2 miles northwest of Dillon Falls, the following section was measured:

	Ft.	In.
Limestone, shaly } *Lower Mercer*	--	7
Limestone, hard, blue } *Lower Mercer*	--	5
Shale, calcareous } *Lower Mercer*	--	2
Limestone, blue, hard } *Lower Mercer*	1	4
Coal, clay, and covered	10	6
Sandstone, shaly	5	--
Sandstone, massive	10	--
Sandstone, shaly, with siliceous shales	11	--
Shale, gray	3	--
Clay shale with widely spaced papery coal	5	--
Clay, siliceous	3	--
Sandstone, massive, cross-bedded	13	10

		Ft.	In.
Disconformity.			
Shale, calcareous		2	5
Shale, hard, black, fossiliferous	*Poverty Run*	--	4
Limestone, gray, very fossiliferous		--	4
Limestone, dark, carbonaceous		--	1
Shale, dark, carbonaceous		2	6
Shale, black, fissile, horizon *Vandusen* coal		7	--

Black fissile shales, in which the Vandusen coal appears, are common features of the horizon not only in Muskingum County but also in several counties in southern Ohio. No coal of value was found in Falls Township.

Licking Township.—The Vandusen coal is poorly represented in Licking Township as it is seldom 1 foot thick. It is usually associated with black carbonaceous shales which in places are fossiliferous. No mining has been done except by stripping in stream beds.

Muskingum Township.—The Vandusen coal is present above drainage in western Muskingum Township along Big Run and its tributaries, but it is everywhere thin and unimportant.

Jackson Township.—But little may be said of the value of the Vandusen coal in Jackson Township. In local areas it thickens to 1 foot or more, but in most places it is thin, bony, or represented only by carbonaceous shales. In Section 22, on land of G. Vickers, the following record was obtained:

		Ft.	In.
Sandstone, massive		30	8
Coal, bony		--	4
Clay shale, dark		--	10
Coal, bony	*Vandusen*	--	4
Shales, dark, with thin coal bands		--	6
Coal, bony		--	3

The member at this place is somewhat abnormal as it is made up of a series of thin impure coals separated by carbonaceous shales or clay shales. This condition, however, was observed at other places. Its position here is 69 feet below the Lower Mercer limestone and 32 feet above the Quakertown coal. The bed lies between the two divisions of the Massillon sandstone, which is conspicuous in this township.

Cass Township.—The Vandusen coal in Cass Township is usually thin and it lies between sandstones in much the same way as in Jackson Township. As a source of fuel its value is small.

Washington Township.—Along the Muskingum River near Symmes Ford and along Symmes Creek near its mouth, the Vandusen coal occurs above drainage and lies directly below or close to the Poverty Run limestone. The section was secured on the property of Mrs. Agnes Compton on Symmes Creek about 1 mile from its mouth:

		Ft.	In.
Limestone, shaly	*Lower Mercer*	1	8
Limestone, hard		--	10
Limestone, shaly		--	8
Limestone, hard		1	6
Shale, dark		--	6
Coal, bony		1	6
Covered		16	4
Limestone, dark, fossiliferous, *Boggs*		--	8
Clay		1	--
Covered		1	--
Sandstone, shaly		10	--
Shale, gray, siliceous		4	--
Limestone, fossiliferous, gray, *Poverty Run*		--	6
Shale, dark		--	4
Coal, *Vandusen*		--	6

The Vandusen coal in this vicinity lies unusually close to the Poverty Run and Lower Mercer limestones. It is a hard, block coal, tending slightly towards the cannel type.

Washington Township, Coshocton County.—In order to extend the stratigraphy of the Vandusen coal entirely across Muskingum County the following measurements, taken near the head of Opossum Run, or just south of Graham Corners in Washington Township, Coshocton County, are given:

		Ft.	In.
Coal, *Lower Mercer*, irregularly bedded, with bony layers, thins in short distance to 6 inches		2	--
Clay, siliceous		2	6
Shale		5	8
Ore, blue, siliceous, sparingly fossiliferous, thickens to 8 inches in places		--	3
Shale, gray	*Poverty Run*	1	--
Shale, dark, calcareous, fossiliferous		--	10
Limestone, gray, fossiliferous		--	3
Coal, bony, *Vandusen*		--	8
Clay, siliceous, light		5	--

In the above locality the Vandusen coal lies about 63 feet below the Lower Mercer limestone, which is relatively the same position as that found in Muskingum County.

Economic Value

The Vandusen coal in Muskingum County is too thin to contribute materially to the fuel supply. At no place observed is the volume such as to justify drift mining under present conditions. Small quantities of coal may be obtained cheaply by stripping in stream beds and in other places along the outcrop where the cover is shallow. As a general thing, the bed is somewhat bony or is broken by shale partings so that the fuel obtainable is low grade. The associated clay is seldom of

sufficient thickness and purity to be worked conjunctly with the coal for ceramic uses and the overlying beds are not often of value.

POVERTY RUN MEMBER

The Poverty Run is the lowest well-defined limestone horizon represented in the Pottsville formation of Muskingum County. It is designated Poverty Run because on this stream the deposit was fully exposed for observation. When completely represented, the member is made up of a thin limestone, a calcareous shale, and a stratified iron ore. Usually, however, the three strata are not present in the same section. The limestone which forms the lowest stratum is light-gray, very hard, somewhat ferruginous, and quite fossiliferous. It seldom exceeds 5 inches in thickness and is broken into rather uniform blocks by joints. Above the limestone lies a shale, which averages approximately 1 foot thick. It is dark-gray, rather soft, notably calcareous, and exceedingly fossiliferous. In places this shale contains ferrous carbonate nodules which often exceed 6 inches in diameter, and which, not infrequently, are traversed by calcite bands. These nodules also contain impressions of molluscan life. The upper stratum, only a few inches in thickness, is a regularly-bedded iron ore. It is also sparingly fossiliferous and is a ferrous carbonate except where weathered along the outcrop to hydrated forms of ferric oxide. The fossils in the Poverty Run member are well preserved, and they represent a marine fauna very similar to that found in the overlying Mercer members. This member, while not persistent, extends across western Muskingum County. The Poverty Run lies on the average approximately 52 feet below the Lower Mercer limestone and about 6 feet above the Vandusen coal. Sections showing its relation to other Pottsville members have been given under Vandusen coal, hence they will not be repeated.

The beds at present have no practical value as the limestone is only a few inches in thickness, and as the iron ore is not only small in volume, but is local and siliceous.

LOWER MERCER OR NO. 3 COAL AND ASSOCIATED CLAY

In an interval averaging about 25 feet in thickness, and lying below the Lower Mercer limestone, three coal horizons are quite distinctly defined in Muskingum County, and these beds or their associated clays are moderately steady except where replaced by sandstone. Each of these beds has been developed sufficiently for drift mining in parts of the State, and each has been called Lower Mercer coal. The lower coal bed lies about 24 feet below the Lower Mercer limestone and, at most, only a few feet below the Boggs limestone and ore, which are exceptionally well developed in central and northern Muskingum County. This lower bed is the most constant in volume of the three and is the one that has been mined in small areas in Vinton, Jackson, and Lawrence counties. As it has been called Lower Mercer coal in

southern Ohio, it will be so named in Muskingum County. The second horizon lies, on the average, about 12 feet below the Lower Mercer limestone, and is the one marked in many places by beds of flint and plastic clay. The coal stratum on this horizon is seldom conspicuous although it has been mined at places in eastern Ohio and on Flint Ridge in Licking County where it is represented by thick beds of cannel coal. The upper coal lies either directly below the Lower Mercer limestone or is separated from it by a few inches of shale, usually carbonaceous. This bed also swells in many places so that it is mined for local consumption, but, as a usual thing, the stratum is only a few inches in thickness.

The Lower Mercer coal, or that lying about 24 feet below the Lower Mercer limestone, is present above drainage in Newton, Hopewell, Springfield, Falls, Licking, Muskingum, Jackson, Cass, Jefferson, Washington, and Madison townships. Although the bed is rather persistent, it rarely exceeds 1 foot in thickness in Muskingum County, and is often marked only by carbonaceous shales or by a smut streak underlain by siliceous clay.

Newton Township.—In Newton Township the Lower Mercer coal is more often represented by carbonaceous shale than by coal of noteworthy thickness. The overlying Boggs limestone was nowhere seen, and the ore was found only in local areas. The following record, taken in the southwestern part of Section 20, illustrates the usual condition of the member in this township and its relation to other beds:

	Ft.	In.
Limestone, *Lower Mercer*	1	2
Shale, dark	--	4
Coal, *Middle Mercer*	--	4
Clay, light, siliceous	2	--
Shale and shaly sandstone	6	9
Coal, *Flint Ridge*	--	1
Clay, light, plastic	3	--
Sandstone, shaly	2	--
Sandstone	3	--
Shale and covered	8	--
Shale, dark, carbonaceous, *Lower Mercer* coal horizon	1	--
Clay, light, siliceous	4	--

The clay on the Lower Mercer horizon is more steady than the coal, and both are often replaced by sandstones.

Hopewell Township.—The Lower Mercer coal is also thin in Hopewell Township, rarely reaching 1 foot in thickness. Its relation to the Boggs limestone is well shown in the following measurements, taken on land of O. J. Riggle, in Section 18:

		Ft.	In.
Limestone, dark-gray, fossiliferous	*Boggs*	1	6
Limestone, dark-gray, very fossiliferous		--	6
Shale		2	2

	Ft.	In.
Coal, *Lower Mercer*	--	3
Clay, light, part siliceous	2	5
Shale	4	--

The relations observed above were duplicated at other places in this township. The coal often changes from a bright bituminous coal to an impure cannel coal or to highly carbonaceous shales. The overlying Boggs limestone is exceptionally thick at this place, and the underlying clay is about normal in both volume and character.

Falls Township.—As the members are traced eastward into Falls Township, no new features are presented. In the main the Lower Mercer coal thickens somewhat, but is usually rather impure. On the headwaters of a western tributary of Bartlett Run, near the home of L. Haines, the bed measures 8 inches and is of a cannel nature. The overlying Boggs limestone assumes the phase of a dark-colored flint which becomes more common as the member is traced northward.

Muskingum Township.—In Muskingum Township the Lower Mercer coal occasionally thickens to 1 foot, but it usually measures only a few inches, and is often marked more by its associated clay than by coal. Its relation to the Boggs member, which is very constant throughout the area, is well defined, as well as its position with reference to the Flint Ridge coal and to the Lower Mercer limestone. In the western half of the township the coal is about 10 inches thick.

In the eastern part of the township along the Muskingum River the member lies much closer to the Lower Mercer limestone. The overlying Boggs member is usually represented by a dark-colored flint, but in places this has given way to an iron ore bed which has good thickness and continuity. The general condition is illustrated by the following section taken along the cut of the Wheeling & Lake Erie Railroad north of Rock Cut:

		Ft.	In.
Limestone, shaly	*Lower Mercer*	1	6
Limestone, hard		1	10
Shale		--	4
Shale, dark, with coal bands		--	6
Coal, cannel nature, bony, *Middle Mercer*		1	3
Clay, often partially replaced by sandstone		4	--
Shale, siliceous, dark-gray		6	--
Flint, ferruginous, dark, varies from 2 to 15 inches, *Boggs*		--	10
Coal, *Lower Mercer*		--	1

At other places along the cut the coal below the Boggs limestone expands to several inches in thickness, and the clay is everywhere well defined. As previously stated, the overlying flint often changes to ore, which condition is found as the member is traced northward into Jackson Township.

Licking Township.—The Lower Mercer coal is rather steady in

Licking Township, but at no place observed is it of sufficient thickness to be of value as a fuel. The overlying Boggs member is more often represented by iron ore than by flint or limestone.

Jefferson Township.—But few exposures of the Lower Mercer coal were observed in Jefferson Township, and in these no new relations were shown. The coal is thin, but the clay usually has good volume.

Washington Township.—In Washington Township the Lower Mercer coal is exposed only a few feet above water level along the Muskingum River in the vicinity of the Ellis Dam. The member at this place is represented by a thin streak of coal underlain by about 3 feet of siliceous clay. It lies just below the Boggs limestone which is represented by calcareous flint and hard sandstone.

Madison Township.—The horizon of the Lower Mercer coal is above drainage along the Muskingum River in Madison Township, but the member is seldom observed on account of the fluvial deposits covering the coal formation rocks. The bed outcrops more often along Symmes Creek from its mouth to the mouth of North Fork. The Lower Mercer coal in this vicinity is thin and the associated clay siliceous. The coal member lies directly below the Boggs limestone and only about 16 feet above the Poverty Run limestone.

Cass Township.—The Lower Mercer coal was traced across Cass Township into Coshocton County. The associated clay is more conspicuous than the coal, and the overlying Boggs member is often marked by a bed of iron ore. Along the road one-half mile west of Dresden the following measurements were secured:

	Ft.	In.
Limestone, Limestone, Limestone } *Lower Mercer*	1	3
	1	6
	--	10
Coal, bony, *Middle Mercer*	--	6
Clay	2	--
Sandstone, argillaceous	5	6
Shale, black, fissile, *Flint Ridge* coal horizon	1	6
Sandstone, argillaceous, light	5	2
Ore, blocky, *Boggs*	--	4
Coal blossom, *Lower Mercer*	--	1
Clay, light, siliceous, lower part shaly	8	--

At other places in this locality the coal on the Lower Mercer horizon is several inches thick, but usually shaly. The interval from the coal to the Boggs ore or limestone is, in many places, several feet, whereas, that to the Lower Mercer limestone is on the average considerably greater than it is in the above section.

Jackson Township.—In Muskingum County the Lower Mercer coal reaches its maximum development in Jackson Township, where in local areas it has a thickness approximating 2 feet. In most of the

region, however, its position is marked only by a thin bed of coal, or by dark carbonaceous shale, or by both. Flint, limestone, and ore are present on the Boggs horizon, but the ore is the most common, and is often present in considerable volume.

At the forks of the road near Fairview School in Section 7, a heavy blossom of the Lower Mercer coal is exposed, and its position is 35 feet below the Lower Mercer limestone. On the land of C. Gearhart, in Section 14, the coal has been prospected, but the opening was closed when the region was visited.

Summary

In Muskingum County a rather persistent coal bed, which in places has fair volume, lies on the average about 24 feet below the Lower Mercer limestone. A bed mined by drifting in local areas in Vinton, Jackson, and Lawrence counties, and there called Lower Mercer coal, is similarly placed. In this southern area it is overlain by the Boggs ore, which in some localities is fossiliferous, thus denoting a limestone horizon. In Muskingum County the coal is overlain by strata which consist of iron ore, calcareous flint, or siliceous limestone, all of which are fossiliferous. The coal and ore, or limestone, of this county are evidently correlative with the coal and ore of southern Ohio, and have been named in accordance. The sections given under Lower Mercer coal also show that two other coal horizons below the Lower Mercer limestone are fairly well defined across the western part of Muskingum County. Associated with the second coal are beds of both flint and plastic clay. Its position is approximately 12 feet below the Lower Mercer limestone. This member will be considered later under Flint Ridge coal. The third coal bed lies directly under the Lower Mercer limestone and is very persistent, but in this area it is thin. This is the Middle Mercer coal and will be discussed under that heading.

Economic Value of the Coal and Clay

The Lower Mercer coal in Muskingum County is unimportant as a fuel supply. The only area that gives promise even of yielding coal for local consumption is a small field in northern Jackson Township of not more than 2 square miles, as the bed lies near the summits of the main ridges. The coal appears to be of good quality. Elsewhere the stratum is so impure that it is worthless for fuel, or so thin that it may only be mined cheaply along stream beds where the fuel is solid and the covering thin. In Muskingum County the average thickness of the bed will not exceed 8 inches, even when the impure layers are also considered.

The clay associated with the Lower Mercer coal in Muskingum County averages less than 2 feet in thickness, but in local areas it occasionally expands to as much as 4 or 5 feet. It is light-colored, gen-

erally siliceous, moderately plastic, and belongs to the buff-burning class of clays usually associated with coal beds. So far no use has been made of this clay as much better and more available deposits are present in the county. In the main it is suitable only for common or building brick, yet in some places its qualities fit it for the manufacture of stoneware. The clay adds but little to the mineral wealth of the county.

BOGGS MEMBER

As has been previously stated, the Boggs member lies at most only a few feet above the Lower Mercer coal and on the average about 22 feet below the Lower Mercer limestone. In ascending order it is the second distinctly defined limestone horizon in the Pottsville formation of Muskingum County. The member is best developed in Hopewell, Falls, Muskingum, Cass, and Jackson townships, although it is also represented in Newton, Licking, Jefferson, Madison, and Washington townships.

The Boggs horizon may be marked by limestone, flint, iron ore, or almost any combination of these rocks. Further, fossiliferous shales are often present. Lithologically this limestone in many respects resembles the Lower Mercer limestone and the flint is similar to that found on the Upper Mercer horizon. At its best this limestone is hard, dense, bluish-gray, and rather siliceous. It is usually ferruginous, and in places so much so that the weathered blocks are highly colored by hydrated forms of iron oxide. In fact it gradates through these stages of ferruginous limestone to calcareous iron ore of the carbonate type. On the other hand it also gradates from siliceous limestone to calcareous flint, or even to that carrying practically no lime. The flint is usually highly colored from iron oxide and carbon, the colors vary from nearly white through grays to black. Limestone and flint are often directly associated, the flint usually occupying the upper position. The iron ore is an impure ferrous carbonate under heavy cover, but along the outcrop, or where severely weathered, it belongs to the limonite class. The limestone and flint are very fossiliferous, but the iron ore has fewer fossils. In the main the types are very similar to those shown in the marine life of the overlying Lower Mercer limestone, although so far the fossils have not been carefully studied and compared.

The term Boggs is applied to the member, as it is correlated with confidence with an iron ore of that name formerly worked extensively for the early furnaces in Scioto County. Its position below the Lower Mercer limestone is approximately the same in Muskingum County as it is in southern Ohio. Further, the associated coal bed, which is well defined in both areas, also agrees stratigraphically, but the marine life preserved in the rocks of the two fields has not been studied.

Newton Township.—Although due over the entire area, the Boggs

is not a conspicuous member in Newton Township. The horizon, however, is marked locally by deposits of siliceous iron ores or of nodular flinty material, lying approximately 20 feet below the Lower Mercer limestone.

Hopewell Township.—The Boggs member is above drainage in the northern part of Hopewell Township and is especially conspicuous along Poverty Run and its tributaries. It is often typically defined at this place, as it is a bed of fossiliferous limestone occasionally overlain by a bed of iron ore. At other places only iron ore or calcareous flint mark the horizon and in some localities the member is not represented or is replaced by thick sandstones. The following record taken on the land of Delard Fink, in Section 18, shows the relation of the Boggs member to the Lower Mercer limestone:

		Ft.	In.
Limestone, blue, fossiliferous	*Lower Mercer*	--	10
Limestone, blue, fossiliferous	*Lower Mercer*	1	4
Covered		10	--
Shale and covered		15	4
Limestone, blue, hard, fossiliferous	*Boggs*	--	10
Limestone, siliceous, ferruginous, fossiliferous	*Boggs*		10

In the above locality the Boggs member is a siliceous limestone containing ferrous carbonate. On weathering the iron minerals in the lower bed are converted into an impure iron ore. Lithologically the upper stratum strongly resembles the Lower Mercer limestone and both beds are very fossiliferous. On the land of Della Wise, near the Wise School, the member is represented by iron ore, dark flint, and hard sandstone, the total thickness of which is about 10 inches. In Section 19, on the farm of Ralph Terry, the Boggs member is composed of 3 inches of ferruginous sandstone and 3 inches of light flint. It lies 17 feet 6 inches below the Lower Mercer limestone. East of the Wise School, on the property of Harrison Shuey, 10 inches of a siliceous, ferruginous, fossiliferous limestone on the Boggs horizon was exposed in the stream bed. In the northern part of Section 14, on the land of H. Drumm, the Boggs member is represented by a true black band ore in which *Lingulae* and *Orbiculoideae* are especially abundant. Along the Licking River in this township, the member is more often represented by iron ore or calcareous flint than by limestone.

Falls Township.—In Falls Township the Boggs member is above drainage along the Licking River and along Big, Bartlett, and Timber runs. The volume of the bed expands in local areas to 1 foot 6 inches, and the composition varies from a true limestone to a ferruginous flint or to a siliceous iron ore. The member is only moderately constant. The following section, taken on the J. Butler farm, 1 mile north of the mouth of Bartlett Run, shows the thickness and structure of the Boggs member:

		Ft.	In.
Flint, light, ferruginous	Boggs	1	--
Sandstone, flinty, ferruginous		--	6
Shale, dark		1	6

The flinty phase of the Boggs member reported in the above section is common in the northern part of this township. The flint is sparingly fossiliferous and is usually of a dark color. The interval to the Lower Mercer limestone is about 35 feet, which is considerably greater than the average. Near the mouth of Big Run, on the M. A. Russel farm, the member is represented by 1 foot 6 inches of a ferruginous, cherty limestone, and west of this, along the Licking River, it has thinned to only 8 inches. Along Timber Run only thin deposits of iron ore were seen.

Licking Township.—The Boggs member is readily traced across Licking Township, but at few places is it more than a thin bed of flint or iron ore. It lies well above drainage, especially in the western part, where it is found near the summits of the main ridges.

The following section, taken along the road south of Claypool School, shows the position of the Boggs member in relation to the Flint Ridge coal:

		Ft.	In.
Coal, bony, *Flint Ridge*		--	8
Clay and clay shale, light		4	--
Flint, light, irregular	Boggs	--	5
Sandstone, hard		--	5
Shale, light		1	--

Muskingum Township.—In Muskingum Township the Boggs member is often a true limestone, strongly resembling the Lower Mercer. The range in composition, however, is from limestone to flint and from limestone to iron ore. The member is above drainage in the entire township, but it lies close to the flood plain along the Muskingum River. In the southern part of Section 6, along the road, 1 foot 2 inches of a dark, fossiliferous flint was exposed on this horizon. Along Blunt Run the Boggs member is exceptionally well exposed in the stream bed. For collecting, this is one of the best localities in the county. The typical stratum is a true limestone which is only slightly ferruginous and not especially siliceous. The overlying shales are calcareous and belong to the same deposition period, whereas the thin kidney ore is also directly related, its position with reference to the higher limestones being about normal. North of this, on Beech Run, the Boggs limestone has changed to one very flinty and generally ferruginous, and along the Wheeling & Lake Erie Railroad, north of Rock Cut, it gradates from a flinty limestone to calcareous flint or to siliceous iron ore.

Cass Township.—In Cass Township the Boggs member is well above drainage and exhibits the various phases of limestone, flint, and iron ore, all of which are fossiliferous. In local areas it has ex-

cellent thickness. Along the road south of Elberson School the Boggs horizon is marked by a few inches of light, calcareous flint, whereas along the road 1 mile west of Dresden it is represented by a blocky iron ore usually about 4 inches in thickness. North of the preglacial Newark Valley iron ore commonly marks the horizon.

Jefferson Township.—The Boggs member in Jefferson Township lies near the base of the hills and about 20 feet below the Lower Mercer limestone. The horizon is generally marked by iron ore.

Washington Township.—In Washington Township the Boggs member is very prominent along the cliff facing the Muskingum River in the vicinity of Ellis Dam, where it lies 20 feet above water level. The exposures in this locality were the only ones observed in Washington Township. The following section, taken near the dam, shows the relative positions of the Boggs member and the Lower Mercer limestone:

		Ft.	In.
Limestone, shaly	*Lower Mercer*	1	--
Limestone, hard		--	7
Shale		--	2
Limestone, hard		1	8
Shale		--	4
Coal, bony, *Middle Mercer*		--	8
Clay, siliceous, with sandstone layers		6	--
Sandstone, shaly		10	--
Shale, blue		1	6
Flint and hard sandstone, *Boggs*		1	--
Clay, light, very siliceous		3	--

The Boggs member in this locality is made up of flint and hard sandstone in varying proportions. The flint, which is dark-colored and sparingly fossiliferous, occurs in the upper part of the bed, and gradates with no true line of demarcation into the sandstone, which is light-colored, and contains no impressions of marine life. Limestone and iron ore were not observed on the horizon.

Madison Township.—The Boggs member in Madison Township is present near the base of the hills along the Muskingum Valley, but it is so deeply covered that few exposures were observed. However, it occurs above drainage along Symmes Creek from its mouth to that of its largest tributary, North Fork, where the bed appears to be very steady and exceptionally well developed, showing all the phases from limestone to flint and iron ore. The Boggs limestone at Symmes Ford is dark-blue and moderately fossiliferous, in general appearance closely resembling the Lower Mercer limestone. The intervals to the Lower Mercer limestone and to the Poverty Run limestone are unusually short, the one to the Poverty Run limestone being only 16 feet. On the farm of Mrs. Agnes Compton, on Symmes Creek, about 1 mile from its mouth, there is only one layer of Boggs limestone, which is about 8 inches thick, and lies 17 feet below the Lower Mercer lime-

stone and 18 feet above the Poverty Run limestone. Another good exposure of the Boggs member occurs in the bed of Symmes Creek near the mouth of North Fork, where it is composed of 4 inches of dark limestone overlain by 4 inches of red ferruginous limestone, both of which carry fossils. This lies only 10 feet below the Lower Mercer limestone, which is the shortest interval found in the county. In the northern part of the township the Boggs member often has exceptional thickness and appears to be very persistent. Along the road one-half mile east of the Little School the bed measured 1 foot 8 inches in thickness, and is a dark, fossiliferous limestone, the upper part of which is more or less flinty. At this place it lies 17 feet above a blue siliceous ore, which represents the Poverty Run member, and approximately the same distance below the Lower Mercer limestone. The Boggs limestone was also observed at other places along the Muskingum Valley east of this. The following record, taken on the farm of James Scott, in the northeastern corner of the township, is given in order to trace the bed as far east as possible, and to show the general character of the member as it passes into Coshocton County:

	Ft.	In.
Limestone, *Lower Mercer*	--	9
Limestone, *Lower Mercer*	--	11
Limestone, *Lower Mercer*	1	7
Coal, bony, *Middle Mercer*	--	5
Clay	1	--
Sandstone, light, shaly	9	6
Shale, blue, siliceous	6	--
Limestone, flinty, dark, *Boggs*	--	9
Clay, siliceous	2	--

The Boggs member at this place is a true limestone; it is somewhat flinty and dark-colored, but in other respects resembles the Lower Mercer. This limestone is moderately fossiliferous and the types of marine life are similar to those in the overlying Mercer limestone.

Jackson Township.—South of the Newark River Valley in Jackson Township, the Boggs member is generally marked by a bed of ferruginous flint or cherty limestone, whereas north of this valley it is more often characterized by deposits of iron ore, which were formerly mined to a small extent for iron smelting. Limestone, however, was seen at a few places north of the valley. The Boggs ore is very persistent along the main ridge north of Frazeysburg, where it is reported to vary in thickness from 6 inches to 3 feet. The average measurement, however, in this locality is approximately 10 inches. In places the ore is partially or completely replaced by flint. Like the limestone and flint the ore is fossiliferous.

Economic Value

The Boggs member is unimportant in estimating the mineral wealth of Muskingum County. The deposits of relatively pure lime-

stone on this horizon are local and seldom reach 2 feet in thickness. The rock is too impure for caustic lime and too hard to be crushed cheaply for agricultural use. However, it may be employed locally for road making where the stratum outcrops along stream beds and is thus readily available. The limestone often gradates into flint, in fact flint or cherty limestone is the most common representative of the member. Further, the limestone and also the flint often change to iron ore, which had considerable value during the early period of iron making in Ohio, but which has little worth at present. Analyses of this ore formerly mined north of Frazeysburg follow:[1]

Specific gravity	3.152	3.464
Water, combined	2.40	10.05
Silicic acid	26.72	3.66
Iron sesquioxide	13.57	79.07
Iron carbonate	43.08	------
Manganese	.60	1.70
Alumina	2.00	2.60
Calcium phosphate	2.64	1.13
Calcium carbonate	4.18	------
Magnesium carbonate	4.24	.65
Magnesium phosphate	-----	.70
Sulphur	.53	.23
	99.96	99.79
Metallic iron	30.28	54.65
Phosphoric acid	1.21	.89

FLINT RIDGE COAL AND ASSOCIATED CLAY

A coal bed lying on the average about 12 feet below the Lower Mercer limestone is especially well developed in a small area on Flint Ridge, in Hopewell Township, Licking County, hence in this report it is called Flint Ridge coal. In the type locality it is a cannel coal with excellent thickness, but in most of Muskingum County it is usually bituminous and seldom very thick, being often only a smut streak. Further, thick beds of clay, part of which is often a true flint clay, are associated with the coal. In this county the clay and not the coal is the important mineral on this horizon. The member is above drainage in Newton, Hopewell, Springfield, Falls, Washington, Licking, Muskingum, Madison, Jefferson, Cass, and Jackson townships.

Newton Township.—In Newton Township the Flint Ridge horizon is generally well marked either by a thin coal bed or by a thick clay stratum or by both. The thickness of the coal is only a few inches, but that of the clay 1 to 5 feet or even more.

[1] Geol. Survey Ohio, Vol. III, p. 244.

At no place observed in this township was the coal of sufficient thickness to be of value aside from furnishing a small quantity of fuel by stripping along stream beds. The clay, however, is of importance, as it is used to some extent for stoneware at White Cottage and at Crooksville, and is considered one of the best clays of the region for this purpose. A section in the mine of W. F. Lenhart, located 1 mile west of White Cottage, follows:

	Ft.	In.
Limestone, *Lower Mercer*	1	1
Shale	--	3
Coal, bony } *Middle Mercer*	--	2
Coal, good } *Middle Mercer*	--	3
Clay, light, siliceous	2	10
Coal, shaly, *Flint Ridge*	--	3
Clay, siliceous, light, lower part ferruginous	5	--
Clay, dark, flinty, siliceous	--	11
Clay, plastic, light-gray	1	8
Clay, light, siliceous	1	9
Clay, dark, somewhat shaly	1	8
Clay, light, siliceous, hard	3	1
Clay, light, plastic	1	2

The portion of the clay deposit used for stoneware lies between the 11-inch stratum of dark flinty clay, and the base of the deposit, and is 10 feet 3 inches thick. It is mined by stripping as the overburden is shallow. The clays associated with the Middle Mercer and Flint Ridge coals, as well as the underlying shales, are worked at Fultonham for the manufacture of building brick. The general thickness and character of the beds are about the same as shown in the section just given.

Springfield Township.—The Flint Ridge member appears above drainage on Thompson Run, but neither coal nor clay is conspicuous. A part of the clay is flinty. In local areas it has fair volume, but so far has not been worked for ceramic purposes.

Hopewell Township.—The Flint Ridge coal in Hopewell Township is very thin, often only a mere carbonaceous stain, but the clay is steady and usually thick. In many places the bed is made up of both the flint and plastic varieties. Just north of Section 11, on land of Monroe Smith, the Flint Ridge coal is represented only by carbonaceous shale, or in places by a thin band of coal. The interval from the coal horizon to the Lower Mercer limestone is above normal. The clay, however, has good thickness and is steady.

In order to carry the stratigraphy of this member to the main coal body, sections taken in Licking County will be given.

Hopewell Township, Licking County.—In a small field north of Brownsville the Flint Ridge coal has been mined by drifting for many years. At this place it is a cannel coal, very hard and lustrous. It,

however, does not extend far as it either runs out or gradates into bituminous coal. On land of Edward Braun, in Section 13, the rocks given below were exposed for measurement:

		Ft.	In.
Limestone, shaly, very fossiliferous	*Lower Mercer*	7	--
Limestone, hard, fossiliferous		--	8
Shale, calcareous		--	2
Limestone, hard, fossiliferous		1	11
Coal, bony	*Middle Mercer*	--	2
Coal, good		--	5
Sandstone, shaly		1	10
Shale, gray		1	--
Shale, dark, carbonaceous		2	8
Coal, bituminous	*Flint Ridge*	1	9
Shale, carbonaceous		--	9
Coal, bituminous		--	10

At this place the Flint Ridge coal and the thin bed of Middle Mercer coal, lying just below the Lower Mercer limestone, are not directly related, as they are separated by about 6 feet of shale and sandstone. Near the residence of J. C. Loughman, $2\frac{1}{2}$ miles north of Brownsville, the Flint Ridge coal has been prospected by short drift mines. The coal, which is reported to be 2 feet 2 inches in thickness, and to be of the cannel type, lies several feet below the Lower Mercer limestone, from which it is separated by shale.

The main coal bench varies in this locality from 3 feet 6 inches to 5 feet in thickness and the lower bench often expands to 1 foot. This deposit of cannel coal is restricted to a small area of not more than 3 square miles. It goes out suddenly or is represented by a highly volatile bituminous coal. The relation of the Flint Ridge coal to the flint and plastic clay found on this horizon is illustrated in the following record taken along the road in Section 11, Franklin Township, on the west side of the ridge:

	Ft.	In.
Limestone, *Lower Mercer*	1	--
Coal blossom, *Middle Mercer*	1	--
Clay, lower part siliceous	6	6
Shale	1	--
Smut streak, horizon of *Flint Ridge* coal	--	1
Clay, dark, flint	1	--
Clay, light, siliceous	9	--

The Flint Ridge coal is represented only by a smut streak, but the associated clays have excellent thickness. The above section is practically a duplicate of many taken in Muskingum County, and it fixes with a degree of certainty the relation between the coal and clay on this horizon.

Falls Township.—Both the Flint Ridge coal and the associated clay are present above drainage in western and northern Falls Township. The coal, seldom expanding to 1 foot in thickness, is often of the cannel

type, although this is usually quite impure. The clay, however, has good volume on the average, and is of both the flint and plastic varieties.

The following section, taken in a ravine about 1 mile north of the tile works on the S. C. Hildreth property, well illustrates the important features of the Flint Ridge coal and associated clay in this township:

		Ft.	In.
Flint, ferruginous	*Lower Mercer*	--	3
Limestone		--	10
Shale, black, with thin coal bands		--	8
Coal, bony, *Middle Mercer*		--	10
Clay shale, gray		1	6
Covered		2	4
Clay shales, with sandy layers		3	6
Coal, bony	*Flint Ridge*	--	4
Coal, cannel		--	6
Shale, fissile		--	1
Clay, part covered, plastic		5	--

The flint clay on this horizon, which averages about 1 foot in thickness, was well exposed at a number of places, and the plastic clay stratum is very persistent.

Muskingum Township.—The character and position of the Flint Ridge member in Muskingum Township are about the same as in the townships to the south. The coal is everywhere thin and generally impure, whereas the clay has excellent thickness and quality, and at one place has been worked for ceramic products. It is above drainage in all of the township.

Jefferson Township.—The Flint Ridge coal and its associated clay present no new stratigraphic features in Jefferson Township. The beds lie near the base of the hills and the clay was formerly worked to a small extent near Dresden.

Washington Township.—In Washington Township the horizon of the Flint Ridge member is above drainage along the Muskingum River from Gilbert to the northern township line, but the best exposures occur in the vicinity of the Ellis Dam. The coal is generally very thin or absent and the underlying clay is either merged with that associated with the Middle Mercer coal or is replaced by local deposits of sandstone.

Madison Township.—The Flint Ridge coal is generally present in the exposures along the Muskingum River and the lower course of Symmes Creek, but where the interval between the Lower Mercer and Boggs limestone is short this stratum is often absent or represented by only a smut streak. The associated clay usually has fair volume but is siliceous, and dark flint clay was seldom observed on this horizon. The general stratigraphic features of the Flint Ridge coal and its associated clay are shown in the following section, taken in a ravine one-half mile south of Symmes Ford:

		Ft.	In.
Limestone, shaly	*Lower Mercer*	2	--
Limestone, hard		--	10
Limestone, hard		1	10
Shale, calcareous, fossiliferous		--	2
Coal, bony, *Middle Mercer*		--	10
Sandstone, irregular		--	3
Clay, siliceous		4	--
Coal, *Flint Ridge*		--	2
Clay, plastic, upper part dark		4	8
Shale, gray, siliceous		6	--

The Flint Ridge coal at other places thickens to as much as 6 inches, but it is generally shaly. The clay usually is between 3 and 5 feet thick and is separated from the overlying Middle Mercer clay by only a few feet of shale or sandstone, or a few inches of Flint Ridge coal, as is shown in the section just given. Under such conditions both clay beds may be mined conveniently and cheaply from the same entry.

Cass Township.—The Flint Ridge member is above drainage in all of Cass Township. The clay is quite steady, but the coal is often represented only by carbonaceous shale. These features are illustrated by the following record measured on the S. Dorsey farm in the central part of Section 5:

		Ft.	In.
Limestone, shaly, very fossiliferous	*Lower Mercer*	5	--
Limestone, hard		--	10
Limestone, part dark flint		1	7
Shale, dark, calcareous, fossiliferous		1	3
Coal, *Middle Mercer*		--	7
Covered		4	6
Shale, gray, part sandy		15	--
Shale, dark		--	6
Shale, hard, black, fissile, blocky, *Flint Ridge* coal horizon		--	10
Clay, light, siliceous		5	--

In the above locality the interval from the Flint Ridge coal horizon to the Lower Mercer limestone is somewhat greater than normal, and the character of the carbonaceous shale indicates a tendency to pass to cannel coal. In fact, it has the appearance of a very impure cannel coal. In the western part of the township, south of the preglacial Newark River Valley, flint clay about 1 foot in thickness is often associated with the plastic clay.

Licking and Jackson Townships.—Owing to the rise of the rocks to the west and north, the Flint Ridge member in Licking and Jackson townships occurs near the summits of the main ridges, or a short distance down their slopes. The coal is everywhere thin, but the clay is well developed.

Economic Value of Coal and Associated Clay

The average thickness of the Flint Ridge coal in Muskingum County is only about 5 inches, and the measurements even in local areas seldom exceed 1 foot. The variation in the character of the member is marked, as it changes from a carbonaceous shale with thin coal bands to a bright, bituminous coal of high purity, or from the bituminous coal to a true cannel coal, very hard and oily, or from the cannel coal to a black, fissile shale with a low carbon content. The bed is much too thin to warrant drift mining or stripping except along stream beds where the coal is solid and the cover shallow. However, if mined as an associated product with the clay it has a small value as the yield of a bed 5 inches in thickness is about 440 short tons per acre, counting 60 per cent available in mining.

The clay associated with the Flint Ridge coal has a ceramic value worthy of consideration. It has been worked to some extent since the early days of the stoneware pottery industry in Muskingum County and has proven very satisfactory. At present it is regularly mined by stripping on the W. F. Lenhart property west of White Cottage. Clay from this mine is hauled by wagon to the Muskingum Pottery Co. plant at White Cottage, and shipped by rail to the A. E. Hull Pottery Co. at Crooksville. The Fultonham Brick Co. also uses this, together with other clays and shales, for the manufacture of various shades and grades of building brick.

The deposit varies in thickness from 1 foot to as much as 10 feet, but it measures on the average about 4 feet. It is usually made up of different kinds of clay. Thus in many localities about 1 foot of flint clay lies at or near the top of the deposit, but the main body of the clay is of the plastic variety, and a part of this may be of the ferruginous type known as "pink eye." The quality of the clays also varies from place to place. The flint clay is usually siliceous and dark-colored, owing to the presence of organic matter. It is quite hard, but on exposure slakes to sharp angular pieces. The plasticity even of the severely weathered clay is low. It is fairly free from nodules of pyrite or ferrous carbonate. This clay was not tested directly, but from its general character it is not considered especially refractory. The plastic clay varies in color from nearly white to dark-gray, and in composition from a highly aluminous to a very siliceous body. The clay in the lower part of the bed in places has a mottled appearance owing to the presence of segregated iron oxide pigments. Several feet of light-colored clay-bond sandstone is frequently found below the stratum of plastic clay. On the whole the beds are rather free from impure coal bands and iron ore nodules. Following are the results of an analysis of the clay from the W. F. Lenhart mine, made by Prof. D. J. Demorest:

Silica, SiO_2	62.59
Alumina, Al_2O_3	22.17
Ferric oxide, Fe_2O_3	2.11
Lime, CaO	.80
Magnesia, MgO	.72
Titanic oxide, TiO_2	1.30
Sodium oxide, Na_2O	.31
Potassium oxide, K_2O	2.48
Ignition loss	8.08
	100.56

H. G. Schurecht of the Bureau of Mines has determined the physical properties of this clay, and some of his results are given below:

The dry strength is poor. The modulus of rupture of the run-of-mine clay is only 132.0 pounds per square inch and that of the washed material 250.7 pounds. A residue of 9.4 per cent is left on the 150-mesh screen, which is rather high. This clay does not vitrify at Cone 4, but softens at Cone 26. Its warpage under load is very high. The apparent porosities of the burned ware are 19.60 per cent at Cone 01; 22.80 per cent at Cone 2; and 14.55 per cent at Cone 4; whereas the volume shrinkages are 7.43 per cent at Cone 01; 8.36 per cent at Cone 2; and 15.14 per cent at Cone 4.

The better grades of the plastic clay are well fitted for the manufacture of stoneware, and in fact it has long been used for that purpose, and any of the varieties are suitable for making building brick which have excellent structure and color. In importance this clay ranks third in Muskingum County, being surpassed by the clays associated with the Lower Kittanning and Tionesta coals.

MIDDLE MERCER COAL AND CLAY

A thin coal stratum known as the Middle Mercer coal lies either directly below the Lower Mercer limestone or is separated from the limestone by shale, seldom exceeding 1 foot in thickness. This coal is as persistent as the overlying limestone, and is found in Newton, Hopewell, Springfield, Falls, Licking, Muskingum, Washington, Madison, Jefferson, Cass, and Jackson townships. The coal varies in thickness from a mere smut streak to about 1 foot, but it averages nearly 6 inches. The composition of the stratum is also variable as it gradates from a pure block coal through impure cannel coal to carbonaceous shale. In the main its fuel value is low. Only along stream beds where the work of stripping has largely been done by erosion has this bed furnished fuel, and there only in small quantities. The position of the Middle Mercer coal and its associated clay with reference to the Lower Mercer limestone has been illustrated in many sections previously given.

The clay lying directly below the coal varies from 1 to 6 feet, but averages about 2 feet 6 inches. It is light-colored, moderately plastic, generally siliceous, and buff-burning. Irregular masses of hard clay-bond sandstone are commonly bedded in the clay, but concretions of

iron ore were seldom observed. Although resembling in general properties the clay associated with the Flint Ridge coal, this clay has less value. These clay strata are often so closely spaced that they may be worked as one deposit. The chief value of this clay is for stoneware and building brick, but better and more available clays are present in large quantities in the county.

LOWER MERCER, BLUE, OR ZOAR LIMESTONE

Stratigraphy and Extent

The Lower Mercer limestone, also known by the names Blue or Zoar limestone, is the most clearly defined stratigraphic unit in the Pottsville formation of Muskingum County, owing to its wide distribution, to its lithologic character, and to its fossil remains. It is widely used by the stratigrapher as is shown by Orton, who states:

> The Lower Mercer limestone is a thin but wonderfully persistent bed that has long been known and used as a geological guide. It received its name (Mercer limestone) from the geologists of the First Pennsylvania Survey, and took quite a conspicuous place in the sections reported by them from the northwestern portion of that State.
>
> Much greater use has been made of it, however, by White and other geologists of the Second Pennsylvania Survey in establishing the order of the same portion of the coal field.
>
> The value of the same stratum in maintaining the order of the lower portion of the series in Ohio was first clearly recognized and emphasized by Newberry. He says of this limestone, that it may be traced almost continuously from the Pennsylvania line to the Ohio River, and that it is one of the most reliable and useful guides in the exploration of the country traversed by it.[1]
>
> The Lower Mercer horizon, in particular, is the one undisputed and indisputable element in the Lower Coal Measures of Pennsylvania and Ohio. In any system of correlation or co-ordination of the different portions of the Lower Coal Measures, this horizon must be taken as the common and accepted basis.[2]

With the exception of a few places where it is replaced by sandstones' the Lower Mercer limestone extends across the western half of Muskingum County and is present above drainage in Newton, Springfield, Hopewell, Falls, Licking, Muskingum, Washington, Madison, Adams, Jefferson, Cass, and Jackson townships. Further, in the eastern part of the county this rock is frequently recorded in logs of wells drilled for oil or gas.

The member is made up of hard limestone, shaly limestone, and calcareous shale. The main body of limestone is hard, dense, and dark-blue or occasionally nearly black. As a rule it is somewhat ferruginous and siliceous in character. In local areas some layers contain irregular masses of flint, or such a quantity of siliceous matter that the rock may be classed as a chert or impure flint. The main deposit of

[1] Geol. Survey Ohio, Vol. V, pp. 13-14.
[2] Idem, p. 16.

hard limestone is made up usually of only a single layer, or of two layers, divided simply by a bedding plane or by a thin stratum of shale, but in a few localities it is composed of three, four, or even five layers, well defined and distinctly separated. Above these beds in a part of the county shaly limestone varying from 1 to 20 feet in thickness is also present. This ranges from dark-gray to almost black, is decidedly fissile, and irregularly banded, owing to changes in composition. The average thickness from 80 measurements of the Lower Mercer limestone in Muskingum County is 3 feet 7 inches where both the shaly and compact layers are included.

The entire deposit contains abundant remains of marine life which are especially conspicuous on weathered surfaces or in the shaly layers. The shaly limestone is exceedingly rich in pelecypods, whereas the hard limestone, which also contains many pelecypod specimens, is notable for the large stems of crinoids and the abundance of brachiopods. The fauna makes certain the marine origin of the deposit.

This limestone in Muskingum County affords abundant material for the paleontologist. The forms are well preserved and the range of species is wide. Good collecting is found in the hard limestone wherever exposed west of the Muskingum River and Moxahala Creek. Suggested localities are at Y bridge, Zanesville, Beech and Blunt runs near Ellis, along Poverty Run south of Pleasant Valley, and along Jonathan Creek near White Cottage. The shaly limestone is not so widely distributed, but contains a profusion of finely preserved fossils. The best localities for collecting are along the stream in northeastern Section 20, Newton Township, along Flint Ridge in both Licking and Muskingum counties, along the stream north of Sandy Ridge School in Muskingum Township, along the stream in southwestern Cass Township, near Fairview School in Jackson Township, and along Irish Ridge in northwestern Cass Township.

Newton Township.—The Lower Mercer limestone is exposed along the courses of all the larger streams in western Newton Township, but owing to the dip of the strata it passes below cover along Moxahala Creek. The member is very persistent except in a few localities along Jonathan Creek where it is replaced by sandstone. Only one layer varying from 1 foot to 2 feet in thickness is present in the greater part of the area. However, in a few localities there is either an additional layer of hard limestone from 6 inches to 1 foot in thickness or a stratum of shaly fossiliferous limestone, seldom exceeding 2 feet in thickness. The average thickness of the member in this township is less than 2 feet. The following record was measured along the road in the southern part of Section 11:

	Ft.	In.
Flint, black, *Upper Mercer*	--	8
Coal blossom, *Bedford*	1	--
Clay, part siliceous	6	--
Shale, siliceous	10	--
Shale and covered	10	6
Shale, dark	4	--
Limestone, *Lower Mercer*	1	6
Clay shale	--	2
Coal, bony, *Middle Mercer*	--	4
Clay	4	6

In the above section there is only one layer, and both the thickness and structure are typical of the Lower Mercer member in most of Newton Township. The thin underlying bed of Middle Mercer coal with its associated clay is common, whereas the rocks in the interval between the two limestones are representative.

Springfield Township.—In Springfield Township the Lower Mercer limestone is above cover along the valleys of all the main streams except those in the southeastern part. In most of the area the member is composed of a single layer of limestone which varies from 1 to 2 feet in thickness. In the bed of the Muskingum River at Zanesville, however, two layers are exposed, as well as a thin iron ore stratum. It is everywhere fossiliferous and in some localities siliceous or cherty.

Hopewell Township.—The Lower Mercer limestone, almost continuous in Hopewell Township, is above drainage in the entire area. In the main, it is made up of a lower layer approximately 1 foot 7 inches in thickness and an upper layer averaging about 9 inches. Above these, shaly limestone is also present in the western part of the township along Flint Ridge. The average interval from this member to the Upper Mercer limestone is 20 feet and to the Putnam Hill 63 feet. The general relation of the Lower Mercer limestone to other beds of importance is shown in the following section taken about 1 mile north of Mt. Sterling on land of Delard Fink:

		Ft.	In.
Limestone, flinty, *Upper Mercer*		--	8
Coal blossom, *Bedford*		--	4
Covered		6	--
Shale		6	8
Coal, *Upper Mercer*		--	4
Clay		1	--
Sandstone		4	--
Covered		3	--
Limestone, hard, blue	*Lower Mercer*	--	10
Limestone, hard, blue		1	4
Covered		10	--
Shale and covered		15	4
Limestone, blue, hard, fossiliferous	*Boggs*	--	10
Limestone, fossiliferous, siliceous		--	10

At this place there is a similarity between the Lower Mercer and

Boggs limestones in structure and composition and in the general types of marine life. The Putnam Hill limestone, although very thin, contains fossils that identify it with that exposed along the Dugway at Zanesville.

Hopewell Township, Licking County.—Along Flint Ridge, in Hopewell Township, Licking County, the hard layers of Lower Mercer limestone are overlain at many places by shaly limestone, the thickness of which varies from 1 foot to as much as 20 feet. This impure limestone is exceedingly fossiliferous, being especially rich in pelecypods. It affords excellent collecting as the fossils are well preserved and as the rock is easily split along the bedding planes, thus exposing the fossils to the best advantage.

Falls Township—Although the Lower Mercer limestone is thin, seldom reaching 2 feet in thickness, in Falls Township it is very steady, and is well exposed along the courses of the larger streams such as Licking River, Timber Run, Bartlett Run, and Big Run. In most of the area the deposit is made up of only one layer of limestone, at few places reaching 1 foot in thickness, but in local areas it has an additional layer above this measuring from 2 to 4 inches. Further, calcareous shales are occasionally present, but shaly limestone similar to that noted on Flint Ridge was not observed. The following record was obtained in a ravine near where the Ohio Electric Railroad crosses the Licking River on land of the Licking View Realty Co.:

	Ft.	In.
Limestone, *Putnam Hill*	1	4
Clay, shale, and covered	36	--
Limestone, flinty, dark, *Upper Mercer*	1	1
Coal, bony	--	2
Shale, dark	--	3
Coal, hard, bony	--	7
Bedford		
Shale, carbonaceous	--	6
Clay, shaly, sandstone and covered	9	3
Shale, dark, carbonaceous	--	10
Coal, good, *Upper Mercer*	--	11
Sandstone, shaly, part covered	6	2
Ore, *Lower Mercer*	--	3
Shale	--	7
Limestone	--	2
Shale	--	4
Limestone	--	8
Lower Mercer		

The section given above not only shows the general structure and thickness of the Lower Mercer limestone in Falls Township, but also its position with reference to the Upper Mercer and Putnam Hill limestones. The limestone layers are very fossiliferous and the interbedded shale often affords excellent collecting. The associated ore lacks continuity.

Washington Township.—The area of Lower Mercer limestone above drainage level in Washington Township is confined to the valley

of the Muskingum River. Owing to the heavy covering along this stream the beds are seldom exposed for observation. In the stream bed near where the Baltimore & Ohio Railroad leaves the Muskingum Valley, the Lower Mercer limestone has the following structure:

		Ft.	In.
Limestone, shaly		1	8
Limestone, hard	*Lower Mercer*	--	5
Limestone, hard		--	10

The general structure of this limestone, where exposed along Blount Run near Gilbert, is about the same as shown above. Along the cliff in the vicinity of the Ellis Dam the lower layer thickens to 1 foot 8 inches, the next layer to 7 inches, and the overlying shaly limestone thins to 1 foot.

Muskingum Township.—The thickness of the Lower Mercer limestone in Muskingum Township is conspicuous, as in much of the area it averages about 4 feet. The member is usually made up of two or three layers of hard limestone, separated by only a bedding plane or by a few inches of calcareous shale. In a few localities these beds are overlain by dark shaly limestone varying in thickness from a few inches to 2 feet. Both the hard and the shaly limestone are very fossiliferous and afford good collecting on account of the many exposures on Big Run, Blunt Run, Beech Run, and along the Muskingum River. Not only is the Lower Mercer limestone well represented in this township, but also the Boggs, Upper Mercer and Putnam Hill limestones have excellent thickness. Moreover, the Vanport or Ferriferous and Hamden limestones are present in restricted areas. In fact, this is one of the best localities in Muskingum County to study the succession of limestones in the Pottsville and Allegheny formations.

A composite section taken along the road and in a ravine northwest of the Sandy Ridge School follows:

		Ft.	In.
Ore	*Hamden*	--	2
Limestone, very fossiliferous		--	10
Clay, light, parts covered, *Lower Kittanning*		16	--
Covered		6	--
Flint, nodular, light, *Vanport or Ferriferous*		1	--
Covered		2	--
Sandstone, shaly		31	--
Shales, part sandy		22	--
Limestone, *Putnam Hill*		5	--
Clay, dark		1	--
Clay, light		2	--
Shale and covered		19	10
Flint, black	*Upper Mercer*	1	1
Limestone, flinty		1	--
Shale, dark		--	2

		Ft.	In.
Coal, bony		--	2
Shale		--	2
Coal	*Bedford*	--	7
Clay, dark		--	8
Coal		1	4
Clay		2	--
Shale		7	--
Limestone, shaly		1	--
Shale		--	2
Limestone, hard	*Lower Mercer*	1	10
Shale		--	1
Limestone, hard		1	9
Shale, dark		--	2
Coal		--	2
Shale	*Middle Mercer*	--	2
Coal		--	3
Clay, siliceous		1	7
Shale, sandy		4	--
Coal, *Flint Ridge*		--	4
Shale, dark, carbonaceous		--	4
Clay, light		2	--
Shale and covered		6	--
Sandstone, shaly		2	--
Shale and covered		5	8
Shale with nodules of flint, *Boggs*		1	--

Licking Township.—Owing to the rise of the strata westward from Muskingum Township into Licking the Lower Mercer limestone is high on the hills in the entire area. The deposit is thin and is usually represented by one or two layers of hard limestone with no shaly limestone lying above. In some areas not only the Lower Mercer member but the Upper Mercer flint and limestone as well are replaced by a massive sandstone which is very irregularly deposited.

Madison Township.—The outcrop of the Lower Mercer limestone in Madison Township is near drainage level along the valley of the Muskingum River and along the lower courses of its tributaries. The thickness varies from 1 to 5 feet, and the structure shows from one to three layers of hard limestone with the thin calcareous shales, usually associated with the more solid stone. The beds are everywhere fossiliferous and of bluish-gray color.

The Lower Mercer limestone is well exposed in the ravines along the lower course of Symmes Creek and along the Muskingum River from the mouth of Symmes Creek to the southern boundary of the township. In the northern part of the area, however, the exposures are less abundant, being confined to the beds of the larger brooks, as the Quaternary deposits along the Muskingum Valley are very thick. The limestone in this township is usually made up of four distinct layers, the upper one being shaly and more fossiliferous than the other layers. The lower stratum is the most massive, averaging about 1 foot 8 inches

in thickness, although the shaly layer has about the same thickness. The other beds, in the main, are about 8 inches thick, and resemble the lower layer in general appearance. These strata are separated by bedding planes or by shale, seldom more than a few inches in thickness.

Adams Township.—The Lower Mercer limestone is above drainage in the northwestern corner of Adams Township, along the Muskingum River, and along Wills Creek for about 1 mile. Owing to the depth of covering, and its position near the level of the flood plain, exposures are few. The following measurements were taken on the bank of Wills Creek about 1 mile from its mouth:

	Ft.	In.
Limestone, flinty, *Upper Mercer*	1	8
Shale	--	6
Coal, *Bedford*	2	4
Covered	18	--
Limestone	--	8
Limestone — *Lower Mercer*	--	10
Limestone	1	4

Jefferson Township.—Owing to the limited area of Jefferson Township, and to the general similarity of its strata to that of Cass Township, no specific statement is necessary further than that the Lower Mercer limestone is present near the base of the hills and has fair thickness.

Cass Township.—The succession of Pottsville and Allegheny limestones is again well exhibited in Cass Township, for not only has the Lower Mercer limestone good development, but the Boggs, Putnam Hill, Ferriferous, and Hamden limestones as well have excellent thickness in parts of the area. The average thickness of the member is almost 5 feet, whereas the maximum measurement is more than 12 feet.

At a place about 1 mile west of Dresden there are three layers of the Lower Mercer limestone, separated only by bedding planes, or by very thin strata of shale. The limestone is hard, bluish-gray, and very fossiliferous. In local areas this limestone has exceptional volume, as shown by the following record, taken on land of J. F. Shaw, located about 1½ miles northeast of Shannon:

	Ft.	In.
Limestone, shaly, very fossiliferous	4	6
Limestone, flinty, very fossiliferous — *Lower Mercer*	6	6
Coal, *Middle Mercer*	--	8
Shales and covered	13	4
Limestone, dark-gray, *Boggs*	1	10

The shaly limestone seen at this place is correlative and similar in appearance to that previously noted on Flint Ridge. It is very fossiliferous and the locality affords excellent collecting. Trilobites are somewhat abundant, as well as the more common pelecypods and brachiopods. The fossils are well preserved and easily obtained. North of the preglacial Newark River Valley the Lower Mercer limestone is very thick in most places, and is made up of both the hard and shaly limestone.

Jackson Township.—In the western part of Jackson Township the Lower Mercer limestone is found only on the highest knobs, but owing to the dip of the strata in the eastern part it extends along the ridges 100 feet or more below their summits. The bed is very persistent, and is composed of both hard and shaly limestone. The thickness varies from 1 to 10 feet, but the average measurement is about 4 feet. The structure is also variable as it is made up of from one to as many as five layers with associated parting shales. On the high knobs in the vicinity of the Fairview School, in Section 7, the shaly limestone above the hard layers is very thick and affords excellent collecting. The maximum thickness is about 10 feet. In that part of the township south of the old Newark River Valley, the member is generally represented by only one layer of limestone, at few places exceeding 2 feet in thickness. The member is best developed in the northeastern part of the township.

Economic Value

The quantity of Lower Mercer limestone in Muskingum County is large, as the member is found above drainage in 12 of the 25 townships, and as the mean thickness obtained by an average of a large number of measurements, is approximately 3 feet 7 inches. Excluding the shaly part the thickness of the soild, hard limestone is between 2 feet 6 inches and 3 feet. In local areas, however, this part is about 4 feet. The yield per acre of a deposit 3 feet in thickness, where the entire bed is available, is approximately 11,000 tons of 2,000 pounds each. Owing to the outcrop conditions along hillsides, and especially along stream courses, large quantities of this limestone are easily available for all purposes for which it may be used. The main body of the Lower Mercer deposit is a hard limestone somewhat siliceous and bluish-gray. It is weather resistant, seldom showing disintegration through the action of freezing and thawing. Further, the effects of solution agencies are not pronounced. The clean stone has an attractive color which darkens slightly on exposure, and it may be used with success for the better grades of building stone.

The composition of the Lower Mercer limestone is shown by the following analysis, which was made by Prof. D. J. Demorest from a sample taken on Beech Run in Muskingum Township:

Silica, SiO_2	8.59
Alumina, Al_2O_3	1.50
Ferric oxide, Fe_2O_3	1.59
Calcium carbonate, $CaCO_3$	83.36
Magnesium carbonate, $MgCo_3$	2.12
Titanic oxide, TiO_2	.05
Phosphorus pentoxide, P_2O_5	.25
Sulphur, S	.75
	98.21

The analysis shows that this limestone is not fitted for calcination as the cementing agencies, the silica, iron oxide, and alumina, amount to 11.68 per cent, which is too high. Such a product slakes with difficulty. The iron oxide is also sufficient in quantity to give the burned lime a gray color, which is undesirable for many uses. The percentage of sulphur and silica excludes this limestone from the field of metallurgical fluxes for either blast furnace or steel furnace purposes. The composition is within the limits required for the manufacture of Portland cement, but the volume of the deposits is too small to justify the establishment of such an industry. Besides the product would not be of the highest grade.

The Lower Mercer limestone may be employed with success for agricultural purposes, but it is not as desirable as the Putnam Hill limestone found in about the same localities. The stone should be crushed very finely, as the impurities prevent ready attack by the acids in the soil. The available calcium and magnesium carbonates are above 85 per cent, whereas the phosphorus pentoxide, although small in quantity, is worth considering. Where other limestones of greater purity are not available the Lower Mercer may be employed for soil enrichment. This member, however, has an important use for road building, as it covers a wide area in western Muskingum County, and as large quantities of the stone are easily available along the hillsides and in the stream beds adjacent to many of the roads upon which it is greatly needed. By using portable crushers the cost of the material placed on the road should be low. The tests made by the State Highway Department show that it is suitable for this purpose, being about the average of Ohio limestones in abrasion, hardness, and toughness, but somewhat low in cementing value. The chief use of this member in Muskingum County is for road metal.

LOWER MERCER OR LITTLE RED BLOCK ORE

The Lower Mercer ore is poorly represented in Muskingum County, for it was observed at only a few places. Where present the member lies about 1 foot above the Lower Mercer limestone, and where measured, it was from 3 to 5 inches in thickness. Under cover the ore is a siderite or ferrous carbonate, but along the outcrop, where subjected to weathering agencies, it is a limonite or ferric hydrate. On the hill just south of the village of White Cottage, in Newton Township, the Lower Mercer ore was well exposed in a ravine where the record given below was obtained:

	Ft.	In.
Ore, *Lower Mercer*	--	4
Shale	1	10
Limestone, *Lower Mercer*	1	2

At the mouth of the Licking River at Zanesville both the Lower Mercer limestone and ore were uncovered near the water level, and

the ore measures 3 inches. The ore was observed at a few places along the Licking River west of this, and along the Muskingum River in the vicinity of Rock Cut. Along the road in the northeastern part of Section 20, Hopewell Township, the member measures 5 inches.

At present the value of this member in Muskingum County is trifling, and even during the days of the charcoal furnaces its rating was low owing to its limited extent. It is one of the rich coal formation ores varying from 40 to 50 per cent iron in the raw state. The content of phosphorus is sufficiently high to place the ore in the foundry class, whereas the manganese is usually about 1 per cent. The ore carries varying quantities of lime and magnesia, which are present as carbonates.

UPPER MERCER OR NO. 3a COAL AND CLAY

In Muskingum County there are two well-defined coal horizons between the Lower Mercer limestone and the Upper Mercer limestone and flint, the lower horizon being thinner and less continuous than the upper. In places the beds are closely spaced, or are separated by only a foot or two of clay or shale, and in other localities they are separated by many feet of rock. Both coals are underlain by clays which are very similar in texture and appearance. The lower coal bed occupies the same stratigraphic position as the Upper Mercer or Webster Block coal of southern Ohio, hence in this report it is designated by that name. The Upper Mercer coal in Muskingum County is not important. It is thin, in few places being more than 1 foot thick, and consists of only one layer, unless separated by bony shale partings. Its stratigraphy, however, will be traced in a general way across the county. The coal is above drainage in Newton, Hopewell, Springfield, Falls, Licking, Muskingum, Washington, Jackson, Cass, Jefferson, Madison, and Adams townships.

The clay associated with the Upper Mercer coal averages about 2 feet 6 inches in thickness, but at places expands to 5 or 6 feet. It is of the usual coal formation type, siliceous, light-colored, and only moderately plastic. Usually the clay is free from concretions of iron ore, and is seldom interbedded with sandstones. Its main features are shown in the sections and discussion that follow. On the farm of J. W. Beam, in Section 20, Newton Township, the following strata were exposed for measurement:

	Ft.	In.
Limestone, dark, flinty, *Upper Mercer*	--	9
Shale, dark	--	2
Coal, cannel, impure } *Bedford*	--	4
Shale, carbonaceous } *Bedford*	--	3
Clay and covered	4	3
Shale, siliceous	7	6
Shale, black, fissile	2	6
Coal, *Upper Mercer*	--	6
Covered	9	--
Limestone, *Lower Mercer*	1	4

In parts of Newton Township the Upper Mercer coal is separated from the Bedford coal by only 2 or 3 feet of clay or shale, and in other parts of the township it is replaced by shaly sandstone. It is usually a bright, block coal, but is thin, seldom having a thickness of 10 inches. The black fissile shale is a common associate of the coal in Newton Township. In the southern part of Hopewell Township, the Upper Mercer coal horizon is more often marked by carbonaceous shale than by coal. The associated clay, however, has fair continuity and volume.

In Falls Township the Upper Mercer coal is usually present. Along Bartlett Run north of Dillon Falls, about 1 foot of shaly coal tending towards the cannel type lies midway between the Lower Mercer and Upper Mercer limestones. In Muskingum Township the Upper Mercer coal is generally replaced by sandstone. As the interval between the Upper Mercer and Lower Mercer limestones is very short, the coal is seldom developed even where shales are present. The same condition is found in Licking, Jackson, Cass, and Jefferson townships. In the vicinity of Ellis Dam in Washington Township, the Upper Mercer coal measures 14 inches in thickness. Along Blount Run east of Gilbert the Upper Mercer coal is present in places, but the bed is thin. In the stream bed near where the Baltimore & Ohio Railroad leaves the Muskingum River, about 1 foot of coal was well exposed on this horizon, lying 8 feet above the Lower Mercer limestone. In Madison Township the coal is generally absent or very poorly represented, but it is present in local areas, and along the road 1 mile east of Dresden measures 15 inches. The coal is above drainage for about 2 miles along Wills Creek in Adams Township, but the bed is generally thin or wanting.

Economic Value of Upper Mercer Coal and Clay

The value of the Upper Mercer coal in Muskingum County is small as the bed seldom reaches 1 foot in thickness, and in a large part of the area it is absent. The quality of the fuel, however, is fairly good. It is a highly volatile bituminous coal with a moderate ash content. It has a blocky structure and a bright luster. The most that may be expected from this deposit is a small quantity of domestic fuel where the stratum outcrops along stream beds so that it may be mined by stripping.

The Upper Mercer clay has fair value for general ceramic work, such as the manufacture of face brick or stoneware. It is fairly plastic, generally siliceous, but somewhat high in basic fluxes. Owing to the large quantity of better clays in this county, and to the fact that the associated coal is not thick, utilization of this clay in Muskingum County is hardly profitable at present.

BEDFORD COAL AND CLAY

Stratigraphy and Extent

The coal stratum lying just below the Upper Mercer limestone is the most valuable bed of fuel in the Pottsville formation of Muskingum County. It extends across the western half of the county, being above drainage in Newton, Hopewell, Springfield, Falls, Washington, Licking, Muskingum, Jackson, Cass, Jefferson, Madison, and Adams townships. The bed is very constant, but varies in thickness from an average of 1 foot 1 inch to a maximum of approximately 3 feet 6 inches. This coal is even more persistent than the overlying Upper Mercer limestone, but both strata are at some places replaced by a massive sandstone. Where the coal does not lie directly below the Upper Mercer limestone, a thin shale usually not more than a few inches in thickness lies between the coal and the limestone or its equivalent black flint. From its position with reference to the Upper Mercer limestone this coal bed is considered correlative with a thin coal stratum lying close below the Upper Mercer ore, the representative of the horizon in southern Ohio. This coal bed was also traced directly from Muskingum County to the important cannel coal field in Bedford Township, Coshocton County, and is therefore called Bedford coal. The member is often composed of two, three, or even four layers of coal, separated by shale or clay partings. It varies in composition from a highly volatile bituminous coal to a true cannel coal, or through this to fissile carbonaceous shale; in fact, the three types of material may be found in the same section. The Bedford coal in local areas in Muskingum County has been mined in a desultory way for many years, and will be drawn upon more largely as the thicker beds become more nearly exhausted.

The clay associated with the Bedford coal has fair volume, averaging about 2 feet 6 inches in thickness. The maximum measurements recorded are from 5 to 7 feet. It is light-colored, moderately plastic, and generally siliceous. No flint clay was observed on the horizon. This clay often gradates into underlying sandstones or shales, but as a general thing the line of demarcation is relatively sharp.

Newton Township.—The Bedford coal in Newton Township varies in thickness from a few inches to as much as 3 feet, and varies in composition from a soft bituminous coal to a hard cannel. In places only the Bedford coal is present between the two Mercer limestones, whereas at other places both this and the Upper Mercer beds are well defined. When the region was visited in 1916 neither member was furnishing fuel, even for local needs. However, the Bedford coal was formerly mined in a small way on Kent Run, in Section 1, where it is reported to be a cannel coal of fair quality, and to be about 10 inches in thickness. The following measurements were made just south of White Cottage:

	Ft.	In.
Shale, dark, siliceous	13	8
Coal, bony	--	4
Coal, good	--	8½
Coal, bony — *Bedford*	--	2½
Coal, good	--	1
Clay, plastic	2	9
Coal, good, *Upper Mercer*	--	9
Clay, shale	1	--
Shale	5	8
Sandstone	8	1
Clay light	--	6
Shale, dark	--	10
Ore, *Lower Mercer*	--	4
Shale	1	10
Limestone, *Lower Mercer*	1	2

At this place the two coal beds between the Lower Mercer limestone and the horizon of the Upper Mercer flint, which is just above the upper coal, are well defined, although only separated by 2 feet 9 inches of a plastic clay.

Springfield Township.—Thick sandstones replace the Bedford coal in parts of Springfield Township, whereas in the remainder of the area it is poorly developed, rarely expanding to 1 foot 6 inches in thickness. Moreover, the deposit where of noteworthy thickness is generally impure, being made up of layers of bony shales interbedded with the strata of good coal. It has been mined only along stream beds where the covering is shallow.

Hopewell Township.—Although the Bedford coal is rather persistent in Hopewell Township, its thickness at only a few places has attracted attention for a fuel supply. The thickness varies from a few inches to as much as 3 feet 6 inches, but the average height is only about 1 foot. It lies close to the Upper Mercer flint or limestone, which forms the roof. The member is above drainage in the entire area and will be traced in a general way. Along the road in the central part of Section 13, south, the following rocks were exposed for measurement:

	Ft.	In.
Flint, light, *Upper Mercer*	--	10
Shale, dark	--	6
Coal, impure, cannel, *Bedford*	--	10
Shale, dark, carbonaceous	1	--
Clay, siliceous, light	1	--
Covered	12	--
Limestone, *Lower Mercer*	1	--

Along this ridge for a few miles the Bedford coal is of the cannel type, but the thickness seldom exceeds 1 foot 6 inches. On the property of Margaret Redding, in the northeastern part of Section 12, the coal thickens locally to 3 feet 6 inches, and has been prospected by a short

entry. The thickness of the coal at this place is exceptional, but the area appears to be small. A part of the coal is somewhat bony, tending towards the cannel type. In the central part of Section 3, south, on the farm of W. Dick, the Bedford coal is exposed in a stream bed, where the following measurements were obtained:

		Ft.	In.
Shale		25	--
Coal	*Bedford*	--	7
Shale		--	1
Coal		1	--
Clay shale		3	--

West of this, on the land of G. L. Starkey, the Bedford coal is 1 foot 6 inches thick. On the hills south of Gratiot the thickness varies from 1 foot to 1 foot 6 inches, and the character of the fuel changes from soft bituminous to dense and shaly coal. West of the Johnson School, on the farm of Ralph Terry, in Section 19, the member, where exposed in a ravine, was 11 inches in thickness. In this locality the coal is replaced in only a few rods by the massive sandstones which are persistent for some distance down the stream. East of this, on the main branch of Poverty Run, on land of Delard Fink, located in Section 18, the bed is only 4 inches in thickness, and lies directly below the Upper Mercer limestone and 21 feet above the Lower Mercer member. On land of Della Wise, in the northern part of Section 18, the thickness observed was 1 foot 6 inches. At this place both the Bedford and Upper Mercer coals are again present in the interval between the Upper Mercer flint and Lower Mercer limestone. The tendency of the upper coal bed to assume a cannel phase is somewhat characteristic throughout the western part of the township. Along the ridge, on land of Harrison Shuey, the thickness of the Bedford coal, where well exposed in a ravine, is 8 inches. On the farm of Walter Swank, north of the Wise School, the bed has been prospected by stripping. The measurement secured follows:

		Ft.	In.
Flint, black, irregular, *Upper Mercer*		1	6
Coal, cannel nature	*Bedford*	--	3
Shale, black		--	1
Coal, hard, cannel nature		1	3

On the property of Harrison Drumm, in Section 14, the Bedford coal was exposed along a stream bed and measured 1 foot in thickness. The coal at this place is also of the cannel type. This same general condition was observed at other places on Flint Ridge and on the hills in the vicinity of Cottage Hill. On the hills north of the Licking River no measurements were obtained, but the bed is reported to be about 2 feet in thickness. It has been mined in a small way by stripping.

Falls Township.—Passing eastward from Hopewell into Falls Township the Bedford coal retains the same general characteristics, that is, it is variable in thickness, structure, and composition, and is

locally replaced by massive sandstones. It is above drainage along the courses of all the larger streams, but has furnished only small quantities of fuel to supply local needs. In a part of the area both the Bedford and Upper Mercer coal beds are present. Along the Muskingum River in the vicinity of Zanesville the Upper Mercer limestone and Bedford coal are replaced by sandstone, but west of this, along the Licking River, they are fairly well developed. A section taken south of the Licking River, on land of the Licking View Realty Co., shows the following:

		Ft.	In.
Limestone, flinty, dark, *Upper Mercer*		1	1
Coal, bony		--	2
Shale, dark	*Bedford*	--	3
Coal, hard, bony		--	7
Shale, carbonaceous, fissile		--	6

West of Dillon Falls, on the W. M. Burgess farm, the thickness of the Bedford coal is about 3 feet. This coal has been mined by drifting in a small way north of Dillon Falls, where it is reported to have about the same measurement as shown on the Burgess farm. North of Sodom School, in the northwestern part of the township, the coal was mined by drifting for several years on the land of H. V. Dockray. No mines were in operation when the region was visited in 1916, but the area, from reports, is not exhausted. The thickness of the deposit is stated to be as follows:

		Ft.	In.
Sandstone		10	--
Coal		2	4
Soot or mother coal	*Bedford*	--	2
Coal		1	6

The coal is reported to be of good quality, as it burns freely and as it is not especially high in ash. It was also mined on the adjacent farm of Edward Gay. The area of thick coal, however, appears to be small. Near the mouth of Big Run, on the M. A. Russel farm, the coal from reports is about 3 feet in thickness. At other places in this locality the Bedford coal thickens slightly, but the thickness and quality are not sufficient to warrant mining by drifting. The blossom of this member was noticed along Joes Run, but no good measurements were obtained. In the northeastern part of the township the coal is replaced largely by sandstone.

Washington Township.—In Washington Township the Bedford coal is present near the flood plain of the Muskingum River north of Zanesville. The bed is generally of fair thickness, but in places it is completely replaced by sandstones. No mines were observed. The following section, taken on the land of O. Schurtz, near Gilbert, shows the general thickness of the Bedford coal in northern Washington Township:

	Ft.	In.
Iron ore, nodular, *Upper Mercer*	--	3
Shale, bony	--	6
Coal, *Bedford*	1	6
Clay	2	--
Sandstone, micaceous	16	--
Covered	3	--
Sandstone, shaly	5	6
Limestone, *Lower Mercer*	1	2

In the vicinity of the Ellis Dam the Bedford coal is less than 1 foot thick. Where exposed along the small stream in the northern part of the township, the member is made up of two benches of impure coal, 4 and 9 inches thick. The parting is 3 inches of dark, carbonaceous shale, and the associated clay is about 2 feet thick and siliceous in character.

Licking Township.—Owing to the rise of the rocks to the west and north, the Bedford coal lies near the summits of the main ridges in Licking Township. South of the Licking River the member is present, but the areas of coal with sufficient thickness for mining, even in a small way, are local, as the bed seldom reaches 1 foot 6 inches in thickness. The usual measurement is about 1 foot, and the quality of the coal poor. North of the Licking River the conditions are about the same, although the bed is very persistent. In the extreme northeastern part of the township the coal thickens locally and is mined by drifting for local use on land of K. M. Frazier where the record given below was obtained:

		Ft.	In.
Flint, black, *Upper Mercer*		--	6
Shale		--	1
Coal, good	*Bedford*	--	3
Clay shale		--	3
Coal, bony		--	2½
Coal, good		2	2
Clay, plastic		2	--

The quality of the fuel in the main bench is very good, especially for domestic purposes, but the area of thick coal appears to be small. West of this, on the farm of Max Nethers, the Bedford coal has also been mined by drifting, and the thickness is reported about the same as shown in the above section.

Muskingum Township.—The Bedford coal is present above drainage in all of Muskingum Township. In the western part it lies high in the hills, but in the eastern part, owing to the dip of the strata, the member outcrops not far above the flood plains of the Muskingum River. It is absent in parts of the area where both the Upper Mercer limestone and its associated Bedford coal are replaced by sandstone. One of the most productive areas of this coal in Muskingum County is found

in the vicinity of Rock Cut where the coal has been mined in a small way by drifting for many years, and is from 2 to 3 feet in thickness.

Along Bartlett Run, in Section 23, the Bedford coal has given place to sandstone. On the land of C. C. Welsh, in Section 14, the coal has been mined by stripping, and the deposit is reported to be 3 feet in thickness. In the vicinity of Shannon the outcrop indicates that the coal is thin and patchy. A blossom about 2 feet thick was observed near Township Hall in sections 12 and 13, but no measurements were secured. North of the Sandy Ridge School the Bedford coal was well shown in a stream bed, where the following record was obtained:

		Ft.	In.
Flint, black	*Upper Mercer*	1	1
Limestone, flinty		1	--
Shale, dark		--	2
Coal, bony	*Bedford*	--	2
Shale		--	2
Coal, good		--	7
Clay, dark		--	8
Coal, good		1	4
Clay		2	--

At this place only one coal horizon is present between the two limestone members. Along Blunt Run the coal is in many places replaced by sandstone, but where present it has a total thickness of about 2 feet, including both coal and partings. On Beech Run, on the J. H. Mattingly property, the structure of the deposit is as given below:

		Ft.	In.
Coal	*Bedford*	--	4
Shale, bony		--	2
Coal, hard		--	6
Shale and bone coal		--	4
Coal, good		1	6

Near Rock Cut the Bedford coal is 2 feet 4 inches thick where exposed along the Wheeling & Lake Erie Railroad. This coal has about the same thickness along the Muskingum River northwest of Rock Cut.

Madison Township.—The area of Bedford coal in Madison Township is confined to the valley of the Muskingum River and to the lower courses of its tributaries. Although the bed is rather steady the coal is generally thin and rarely expands to 3 feet. It is not mined even for local use. The following measurements were taken along the small stream about 1 mile south of Symmes Ford, where the coal was well exposed:

		Ft.	In.
Flint, black	*Upper Mercer*	1	2
Limestone, flinty		1	4
Shale, carbonaceous		--	1

		Ft.	In.
Coal, bony	*Bedford*	--	4
Clay		--	2
Coal		1	4
Shale		--	2
Coal with thin shale partings		1	4
Clay and covered		3	--

Although the Bedford coal has good thickness in this locality, it thins to about 1 foot at Symmes Ford. Along Symmes Creek, near its mouth, the member is made up of two layers of coal, the upper one 4 inches thick and the lower one 1 foot 4 inches, separated by shale. The coal is highly volatile and somewhat bony. Farther up Symmes Creek the coal thickens to about 3 feet. In the northern part of the township this coal is generally less than 1 foot 6 inches thick and in places it is replaced by sandstone.

Adams Township —The Bedford coal is above drainage in Adams Township for only about 2 miles along Wills Creek and, owing to the depth of covering along the valley, the bed is seldom exposed. The following section, taken about 1 mile east of the mouth of Wills Creek, is probably representative of the coal in this area:

	Ft.	In.
Limestone, flinty, *Upper Mercer*	1	8
Shale	--	6
Coal, *Bedford*, with thin shale partings	2	4
Covered	18	--
Limestone, *Lower Mercer*	2	10

Jefferson Township.—In the hills south of Dresden the outcrop conditions indicate that the Bedford coal is from 1 foot to 1 foot 6 inches in thickness, but no exact measurements of the bed were obtained under cover or along ravines where the coal was solid.

Cass Township.—The Bedford coal is very steady and has fair volume in most of that part of Cass Township south of the preglacial Newark River Valley, but north of this waterway it is generally thin and in many places absent. It lies high on the hills and is associated with the black flint or the flinty limestone, which was traced from this locality to the important field of cannel coal near Warsaw in Coshocton County. In Cass Township, however, the coal is bituminous, but highly volatile. It is what is generally called a short fibre cannel coal.

West of Dresden, in the vicinity of Elberson School, no exact measurement of the solid fuel of the Bedford stratum was obtained, but the weathered coal along the outcrop is about 2 feet in thickness. South of the Elberson School 1 mile, on the farm of W. Beal, coal was mined from this bed by drifting. The stratum is reported to be 2 feet in thickness and the fuel to belong to the cannel type, but to be of fair quality. The coal lies very close to the Upper Mercer limestone and flint. Along the Highlands near the Dutch School the Bedford

coal has been mined in a small way for local fuel. No mine measurements were obtained, but the bed is stated to be about 2 feet in thickness. Along the ridge west of this the outcrop conditions indicate that the coal has fair volume and that it is of a cannel nature, but somewhat impure. Along Irish Ridge north of the preglacial Newark River Valley, the Bedford coal is generally thin, seldom reaching 2 feet in thickness. In local areas it is replaced by sandstones.

Jackson Township.—South of Frazeysburg along the Highlands, in Jackson Township, the Bedford coal has been mined in a desultory way for many years for local use. North of the Newark River Valley the area of coal is small as the bed is found only in the high hills in the northeastern part of the township, and judging from outcrop indications the volume is generally thin. South of Frazeysburg, on land of Samuel McCann, the coal belongs to the cannel type and is somewhat bony. The bed is reported to be variable in thickness, as in places it decreases to less than 2 feet. This coal has also been mined on the farm of F. Nethers, where it is stated to expand from 2 to 3 feet. In this locality the best of the coal is largely exhausted. South of this, in the central part of Section 21, on the property of W. McCann, the following record was secured in a small mine:

		Ft.	In.
Sandstone, shaly		2	--
Coal, bony	*Bedford*	--	2
Clay shale	*Bedford*	--	2
Coal, good	*Bedford*	2	7
Clay		1	--

The Bedford coal in this locality is mined for neighborhood use. It is a highly volatile, free-burning fuel, with a bulky ash. Along the ridge east and south of the mine just referred to there is a small area yet available. This bed also has good volume in Section 22, and has been mined at a few places. The thickness reported is from 2 feet to 2 feet 6 inches. At a few places along the ridge known as the Highlands the Upper Mercer black flint was observed lying directly below a massive sandstone. The identity of this coal is established by its position with respect to the Putnam Hill and to the Lower Mercer limestones. On the ridges north of Frazeysburg the Bedford coal has but little value, as the bed is generally thin, and in places the covering shallow.

Economic Value of Bedford Coal

From outcrop indications the area of Bedford coal in Muskingum County exceeding 1 foot 8 inches in thickness is approximately 15 square miles. The chief value of the member is that it may furnish for many years a local supply of domestic fuel in the western part of the county, where other beds with greater thickness are confined to small areas and are now largely exhausted. Counting 60 per cent available in mining

this bed where 1 foot 8 inches in thickness will yield approximately 1,800 tons per acre. The general mining conditions are very good as the roof of the coal is either the Upper Mercer limestone and flint which under cover are strong and solid, or a massive sandstone, which in local areas replaces the limestone. In some areas a few inches of shale separates the coal from the overlying limestone or sandstone, and this shale must be removed. Further, the floor of the coal is clay, which owing to its general siliceous character is sufficiently firm to support the weight of the overburden resting on the posts and pillars in properly operated mines. With few exceptions the deposit contains clay or shale partings and bony coal layers, which must be thrown back in the rooms or removed from the mine. The thickness of this parting varies from 1 inch to a maximum of 1 foot, but as a general thing it is from 2 to 4 inches and is not especially troublesome. The clay or shale partings often aid materially in mining as the cutting may be done in them, thus saving coal.

A sample of the Bedford coal from the mine of Max Frazier, in the northeastern corner of Licking Township, was taken by R. E. Lamborn and the writer in July, 1917. The sample was taken well under cover, where the coal was fresh and dry. The analysis was made by Prof. D. J. Demorest:

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	67.35	Moisture	5.56
Hydrogen	5.32	Volatile matter	39.49
Oxygen	13.24	Fixed carbon	44.93
Nitrogen	1.25	Ash	10.02
Sulphur	2.82		
Ash	10.02		

Calorific value { 6,719 calories. / 12,094 B. t. u.

Fusion of ash { incipient 1,204° C. / complete 1,460° C.

The air drying loss of moisture, 1.6 per cent.

In Muskingum County the Bedford is an oily and highly volatile fuel, being either a soft cannel coal or tending towards that class of rocks. It ignites readily, burns freely, and gives a long bright flame. The heating qualities are rather low. In the better grades of this coal the ash is moderate in quantity and clay-like in character. It is light and powdery and clinkers only at high temperatures. The soot produced in burning is not especially troublesome; neither are the sulphur fumes. This coal is well adapted for domestic use and for burning ceramic ware. Further, it is valuable in the enrichment of illuminants in ordinary coal gas and in the production of the lighter

mineral oils. The coke produced is of little value except for minor uses as the structure is poor and as the ash is generally high.

Economic Value of Bedford Clay

The Bedford clay in Muskingum County is of no great importance owing to the large quantity of other clays readily available and better suited for ceramic purposes. The bed has fair volume, often being from 3 to 5 feet in thickness, but it is variable both in thickness and in quality. The clay is generally siliceous and is somewhat high in fluxing oxides. It is everywhere plastic in character, no flint clay being observed on the horizon in this county. The clay is best fitted for the manufacture of buff and iron-mottled building brick, although the best grades may be used for the production of stoneware. The value of the clay deposits will be considerably increased if worked in connection with the Bedford coal where this has fair volume. Where the clay is 4 feet thick and 60 per cent is available in mining, the yield per acre is approximately 8,170 tons of 2,000 pounds each. Counting 3.5 tons clay per 1,000 brick this will make 2,334,000. If economy is practised, .8 ton coal will burn 1,000 brick; hence 1,867 tons coal are required for 2,334,000 brick. As previously shown, this is approximately the quantity of fuel that the Bedford coal will mine per acre where 1 foot 8 inches thick and where 60 per cent is available. Hence the coal under the above conditions will burn the associated clay into ware. To this of course must be added the fuel required in the manufacture of the ware. In Muskingum County at present the Bedford clay is not used for ceramic purposes, but formerly it was employed by country potters to a small extent for making stoneware.

UPPER MERCER OR GORE LIMESTONE

The Upper Mercer limestone is often referred to as the Gore member and attracts attention in Muskingum County, not for its economic value or stratigraphic relations, but for its composition, as it is generally a dark-colored flint. The bed extends almost continuously across the western half of the county except where replaced by massive sandstones. The horizon is due above drainage in Newton, Wayne, Springfield, Hopewell, Falls, Washington, Madison, Muskingum, Licking, Cass, Jefferson, Adams, and Jackson townships.

Where the member is limestone it is uniform in both physical appearance and chemical composition. It is often, however, slightly darker in color owing to ferruginous and carbonaceous components and generally somewhat more siliceous. In Muskingum County the most conspicuous feature by far is the frequency with which the member is represented by dark or even coal-black flint. In fact its representation by limestone is the exception to the rule. The coloration is due to carbon pigments augmented by iron compounds. The flint is very

dense and solid except for small irregular cavities distributed indiscriminately throughout the mass. These cavities are often lined with transparent quartz crystals, which contrast strangely with the black background and which are evidently of secondary origin, having been deposited from solution after the main bed was laid down. The flint is vitreous except where sandy material and weathered iron oxides are present. The purer varieties are brittle, lustrous, and break with a deep conchoidal fracture. The blocks exposed along the outcrop are more or less shattered and traversed by a network of fine cracks owing to expansion due to heating and cooling. Under deep cover, however, the mass is very solid except for regular joint planes spaced a little greater distance apart than the bed is thick.

Both the flint and limestone are fossiliferous, but not to the same extent as either the underlying Lower Mercer member or the overlying Putnam Hill bed, which contains abundant evidences of marine life. The fossils in the Upper Mercer are very similar to those in the Lower Mercer, but this is to be expected as the beds are separated by only a short interval. The fossils in the flint, although not abundant, are seldom effaced or indistinct. Many show all the delicate markings of the original shell.

Both the upper and lower surfaces of the flint bed are very irregular, but this apparently is not due to a concretionary or nodular arrangement. The material is peculiarly mottled, but is not banded. At some stage during the formation of the bed the material was evidently gelatinous silica, but its origin is not clear.

In Muskingum County the Upper Mercer member is seldom made up of more than one stratum of limestone or flint, but in Perry County to the south and in Coshocton County to the north, it is often composed of two, three, four, five, or even six layers separated by bedding planes or by thin beds of shale. The average volume of the deposit in the area under consideration is about 1 foot 5 inches. The mean interval from the Upper Mercer member to the Lower Mercer limestone is 23 feet 5 inches, but the maximum and minimum measurements made by the Survey are 43 feet and 15 feet respectively. The average interval from this bed to the Putnam Hill limestone is 45 feet 2 inches, but the variations are from 20 to 70 feet.

Newton Township.—Northwest of Roseville, in Section 32, the Upper Mercer flint and limestone were exposed along the road, and measured 10 inches in thickness. The upper part was a black flint, whereas the lower part was a dark-gray limestone, with some nodules of flint scattered through it. In this part of the township the bed varies between flint and flinty limestone. The section given below, and taken on the farm of J. W. Beam, in Section 20, shows the general condition of the Upper Mercer limestone in the central part of the township.

	Ft.	In.
Ore, siliceous, *Upper Mercer*	--	6
Limestone, dark, flinty, *Upper Mercer*	--	9
Shale, dark	--	2
Coal, cannel nature — *Bedford*	--	4
Shale, bony	--	3
Clay and covered	4	3
Shale, siliceous	7	6
Shale, black, fissile	2	6
Coal blossom, *Upper Mercer*	--	6
Covered	9	--
Limestone, *Lower Mercer*	1	4
Shale and covered	63	8
Limestone, *Maxville*	10	--

Along Jonathan Creek, in the vicinity of Fultonham, the Upper Mercer is a dark-colored flint, varying from 6 inches to 1 foot 6 inches in thickness. Along Kent Run, in the northwestern part of the township, the bed is very persistent, and at many places reaches 2 feet in thickness. In this locality it is a dark or black flint. The conditions are about the same in the vicinity of Elizabeth, where the member is exposed low on the slopes of the main ridges.

Springfield Township.—The Upper Mercer flint or limestone in Springfield Township is in many places replaced by massive sandstones, but otherwise the bed is about the same as it is in Newton Township, where the rock is more often black flint than limestone, and where the stratum varies in thickness from 6 inches to 2 feet. The member is above drainage in all of the area, but in the eastern part it lies not far above the bed of the Muskingum River. This flint is exposed at many places along Thompson Run, but is seldom seen in the northern and eastern parts of the area, owing to replacement by sandstone.

Hopewell Township.—In Hopewell Township the Upper Mercer flint, rarely limestone, is almost continuous, and the bed varies from 8 inches to 2 feet in thickness. It is decidedly weather resistant, and the large blocks, strewn along the stream beds, or along the hillsides, are conspicuous. Some of the lower pits dug along Flint Ridge by the aborigines were excavated for the purpose of quarrying this material for the manufacture of their crude implements, such as arrows, knives, scrapers, etc., many of which may yet be found in cultivated fields near-by. The strength and durability of this flint, together with its black lustrous color, evidently made it desirable for such uses.

Along the road, in the central part of Section 13, the following record was obtained, and it shows the stratigraphic relations of the Upper Mercer member to other well-known beds:

	Ft.	In.
Limestone, shaly, fossiliferous, *Ferriferous*	8	--
Covered	3	--
Sandstone, massive	15	--

	Ft.	In.
Covered	53	--
Flint, light, ferruginous, *Upper Mercer*	--	10
Shale, dark	--	6
Coal, cannel nature, *Bedford*	--	10
Shale, dark, carbonaceous, siliceous	1	--
Clay, light, siliceous	1	--
Covered	12	--
Limestone, *Lower Mercer*	1	--

Along Thompson Run, south of Mt. Sterling, the Upper Mercer flint is generally replaced by massive sandstones. Along the courses of Poverty Run and its tributaries the deposit is very steady, and varies in thickness from 8 inches to 2 feet. It is also steady in the northern part of the township from the village of Cottage Hill to the Licking River. The color is characteristically dark or black, and the thickness is seldom more than 1 foot 6 inches.

Falls Township.—The Upper Mercer flint or limestone is above drainage in all of Falls Township, but on account of the dip of the rocks to the south and east, it lies close to the flood plains of the Licking and the Muskingum rivers in the vicinity of Zanesville. At this place, however, the bed is often replaced by thick sandstones. It presents no new features, for it is with few exceptions a black or very dark-colored flint, and has an average thickness of about 1 foot. The general stratigraphy and character of the Upper Mercer limestone member in Falls Township are shown by the following section of the rocks exposed on the W. M. Burgess farm, located about one-half mile west of Dillon Falls:

		Ft.	In.
Flint, black, ferruginous, *Upper Mercer*		--	7
Shale		--	2
Coal, cannel, bony	*Bedford*	--	2
Clay shale		--	4
Coal, cannel, bony		2	9
Clay and shale		4	4
Coal, bony, *Upper Mercer*		--	4
Clay shale, siliceous		1	4
Sandstone, hard, plant-marked		1	4
Shale, dark		2	--
Limestone, *Lower Mercer*		--	7

This section was practically duplicated at other places along the Licking River, except that the flint bed in local areas is a mixture of both flint and limestone or flint and iron ore.

Wayne Township.—The Upper Mercer flint or limestone, or its equivalent, is due along the east bank of the Muskingum River in northwestern Wayne Township in the vicinity of Zanesville. The bed, however, was not observed, as the area is largely covered by alluvium, and as it is often replaced by a massive sandstone well exposed at Putnam Hill.

Washington Township.—In Washington Township the Upper Mercer flint or limestone is due above drainage along the valley of the Muskingum River and along the lower courses of its larger tributaries. For some distance along the river north of Zanesville the bed is absent or covered, but along the valley in the vicinity of Gilbert and Ellis the dense black flint, which represents this member, is conspicuous along ravines and hillsides. The following measurements, taken along the cliff near the Ellis Dam, show the Upper Mercer member with good development:

		Ft.	In.
Limestone, *Putnam Hill*		4	6
Covered		50	--
Flint, black, ferruginous	*Upper Mercer*	1	10
Limestone, dark, flinty	*Upper Mercer*	--	9
Coal blossom, *Bedford*		--	3
Clay and clay shale		8	--
Coal, good, *Upper Mercer*		1	2
Clay		1	4
Shale, siliceous		10	6
Limestone, shaly	*Lower Mercer*	1	--
Limestone, hard	*Lower Mercer*	--	7
Shale	*Lower Mercer*	--	2
Limestone, hard	*Lower Mercer*	1	8

Madison Township.—No additional noteworthy features of the Upper Mercer flint or limestone were noticed in Madison Township, except that the bed in places thickens to as much as 5 feet, and that the flint, which is the prevailing rock, is there very black and lustrous. The general stratigraphic features are shown in the following section, taken near the crossroads on Symmes Creek about 1½ miles from its mouth:

		Ft.	In.
Flint, black, irregular	*Upper Mercer*	3	--
Limestone, flinty, very fossiliferous	*Upper Mercer*	2	3
Shale		--	1
Coal, bony	*Bedford*	--	5
Shale	*Bedford*	--	2
Coal, bony	*Bedford*	1	2
Clay, siliceous		3	--
Covered		3	--
Sandstone, shaly		7	--
Shale, siliceous		5	--
Limestone, shaly	*Lower Mercer*	1	6
Limestone, hard	*Lower Mercer*	--	9
Limestone, part shaly	*Lower Mercer*	--	5
Limestone, hard	*Lower Mercer*	1	11

The Upper Mercer limestone in this locality is very fossiliferous and affords good collecting. The above section, besides showing this member with exceptional thickness, shows the Lower Mercer limestone in good development, and the general intervals separating these members

in this township. In the vicinity of Symmes Ford, the Upper Mercer is about 2 feet 6 inches in thickness, being approximately half flint and half limestone, the flint occupying the upper part of the bed. In the hills east of Dresden, the member is usually a flinty limestone about 1 foot 6 inches in thickness, but along the Muskingum Valley, in the northern part of the township, it is more often flint, containing irregular masses of limestone, and measuring from 1 foot 6 inches to 3 feet. A massive sandstone replaces the Upper Mercer limestone in local areas in this township, and it is prominent also in parts of Cass and Jackson townships.

Adams Township.—The Upper Mercer limestone is present along Wills Creek for more than 3 miles from its mouth, but owing to the depth of covering, the bed is seldom sufficiently exposed for measurement. At the few places observed it is a flinty limestone about 1 foot 8 inches in thickness, and is very fossiliferous.

Jefferson Township.—The area of Upper Mercer flint or limestone in Jefferson Township is so small that little needs be said regarding it, except that the bed is generally present high on the slopes of the hills, and that it is black flint varying from 1 to 2 feet in thickness.

Muskingum Township.—The Upper Mercer flint or limestone may be traced almost continuously across Muskingum Township, as the horizon is present along the courses of all the larger streams, and as the bed is very persistent. The member and its position with reference to other beds are shown below in the record taken along the road near the township hall in Section 13:

	Ft.	In.
Ore, siliceous, soft, *Ferriferous*	--	6
Shales and covered	52	--
Limestone, *Putnam Hill*	3	--
Coal blossom	1	--
Clay, shale, and covered	10	--
Covered	7	--
Ore, kidney, *Upper Mercer*	--	6
Shale	7	--
Limestone, with large masses of black flint, *Upper Mercer*	1	6

At other places in this locality the bed was all flint and from 1 foot to 1 foot 6 inches thick. In the hollow north of the Sandy Ridge School the structure is as follows:

		Ft.	In.
Flint, black Limestone, flinty	*Upper Mercer*	1 1	1 --

Along the Wheeling & Lake Erie Railroad, north of Rock Cut, the bed averages about 2 feet in thickness and varies in composition from flinty limestone to impure flint. In this locality it lies rather close to the Lower Mercer limestone with an interval of 10 to 17 feet. The interval to the Putnam Hill limestone is also somewhat less than

normal as it is only 30 to 35 feet. Along Beech Run, the Upper Mercer varies in thickness from 1 to 3 feet, and in composition from a dark-gray limestone with fair purity through limestone with irregular masses of flint promiscuously spaced to dark or coal-black flint with no limestone.

The Upper Mercer, usually represented by black flint, is locally replaced by thick sandstones along the headwaters of Blunt Run. The thickness of the bed where measured is from 1 to 2 feet.

Licking Township.—Owing to the rise of the rocks to the west, the Upper Mercer limestone or its equivalent, the black flint, is found high on the hills in the eastern part of Licking Township, and is wanting in much of the western part. Along the high ridge, an extension of Flint Ridge, in the southwestern part of the township, the Upper Mercer deposit is about 1 foot in thickness, and is a dark flint very similar to that in Hopewell Township. The hills along the Licking River, and those in the western part of the area north of this stream, are not sufficiently high to carry the bed. The flint stratum is present and is somewhat persistent in the hills in the northeastern part, but the thickness where observed rarely exceeds 1 foot.

Cass Township.—The main features of the Upper Mercer flint or limestone in Cass Township are strikingly similar to those in Muskingum Township. In the southeastern part of the area the bed is about 2 feet in thickness, and is composed of flint or flint and limestone; whereas in the southwestern part it is generally thinner, but is the same in composition.

The conditions are about the same eastward along The Highlands to near Dresden, where the member thickens locally and contains both flint and limestone. This is illustrated by the following section taken along the road that leads southwest from the town:

		Ft.	In.
Limestone, *Putnam Hill*		2	--
Clay and covered		7	--
Sandstone, shaly		11	--
Shale		4	2
Flint, black	*Upper Mercer*	--	8
Limestone, with irregular masses of flint	*Upper Mercer*	1	2
Shale		--	4
Coal		--	4
Clay		4	4
Sandstone		5	--
Coal, *Bedford*		1	6

In that part of Cass Township lying north of the broad, preglacial Newark River Valley, the Upper Mercer member lacks continuity as it is replaced by sandstone in so many places. Where present, however, the bed is generally thin and is a dark, ferruginous flint.

Jackson Township.—In Jackson Township, the Upper Mercer flint or limestone is confined to small areas on the high ridges, both in the northeastern part of the township north of the Newark River Valley, and in the southeastern part south of this old waterway. The bed in every respect resembles that described in Cass Township; hence it will not be considered further.

Character and Origin of the Flint

The flint in the black layers is very solid and dense except for small cavities, which are irregularly spaced and frequently lined with transparent quartz crystals. The gray flint is also solid, and has a banded and somewhat mottled appearance, probably due to original deposition, and the analysis shows it to be anhydrous or nearly so. The coal formation flints seldom contain more than 2 per cent of water. Flint has a hardness comparable with that of quartz, and it breaks with a deep conchoidal fracture, the perfection of which depends on the texture of the material. This characteristic fracture is much more evident in the compact, vitreous varieties than in the more porous, grainy types which are mixtures of amorphous silica and quartz sand or calcareous or argillaceous material. It varies from nearly transparent to coal-black, and from the strikingly mottled or banded types to those traversed by small veins of different colored material of later formation.

Three views are tenable as to the origin of the flints associated with the limestones or stratified on the horizons of these rocks:

(a) That the flint was formed by direct precipitation of the siliceous matter by silica-secreting organisms.

(b) That the flint was the resultant of chemical action of soluble silica and other components in the sea water upon the calcium carbonate of newly formed limestone. In this case the change took place while the limestone was forming or while it was yet under the direct influence of the salt brines.

(c) That circulating ground waters, charged with siliceous and organic components which acted upon limestone deposited under normal conditions and buried by later sediments, slowly removed the calcium carbonate and deposited silica in its place. This action began as soon as the beds were covered by other material and is still effective. Under this condition the flint is entirely of secondary origin.

In regard to the first view, it is necessary to account for large quantities of soluble silica and a means of precipitating it. The flint beds found in the coal formations of Muskingum County are directly associated with limestones, or more often occur on the horizons of these rocks. Judging from fossil and other evidence, these limestones are of organic origin and were laid down in shallow basins of the sea. The

natural inference is, therefore, that the flint has a similar derivation. Some of the low forms of life, such as radiolaria, sponges, and diatoms, which inhabit both fresh and salt water, secrete silica. Such material secreted by an organism is hydrous and glassy and is readily dissolved by waters containing carbonates of the alkalis or alkaline earths. Carbon dioxide from a living or a decaying organism, however, readily precipitates this silica. It is also thrown down by hydrolysis in the presence of weak acids such as may occur from decaying organic matter. The rocks on these flint horizons show that a profusion of life existed in these early seas, a part of which was evidently silica-secreting, and the presence, or rather decay, of which would produce conditions often favorable for the direct deposition of silica.

Some of the flint deposits in the coal formations of Muskingum, Perry, and Coshocton counties suggest such an origin. The material is very free from calcium and magnesium carbonates, has the mottling characteristic of gelatinous precipitates, and shows no distinct nuclei attending concretionary growth. Further, the relation of flint beds to limestone strata in some localities is also of interest. As noted in some of the preceding sections, a flint layer may lie either directly above or directly below a limestone which is very free from flinty material. Laterally the rocks often pass in a regular way from limestone or from sandstone to flint in about the same way as shale to sandstone or carbonaceous shale to coal. Flint deposits are also nearly as abundant in the Pottsville and Allegheny formations of this area as limestone deposits. With varying conditions in these shallow seas where both siliceous and calcareous matter are being secreted, flint should result as one extreme and limestone as the other.

The second view is closely related to the first, but it differs in that soluble silica replaces the calcium carbonate of newly formed sediments. As shown by several writers, the replacement of the calcium carbonate of shells, corals, etc., by silica is easily effected. The most favorable conditions would be where both silica and calcium carbonate are being secreted contemporaneously by organic life .Such silica is very soluble and the calcium carbonate is in a state which can be readily attacked, thus making replacement easy. The alkalinity and pressure of the water also aid in this work. The waters of these ancient seas contained a profusion of both plant and animal life, secreting either silica or calcium carbonate; they were warm, owing to the shallow depth and to the prevailing climate, and were partially saturated with mineral and organic components which aid in chemical action, all of which conditions favored replacement changes attending deposition.

Such an origin appears plausible for some of the flint strata in the coal formations of this area. In a certain bed, as the Upper Mercer for instance, flint may be overlain by limestone or limestone by flint,

or the two may occur in almost any proportion. Substitutions are apparent, but it is difficult to determine whether they took place during the early period of formation or during a later period by the action of circulating waters. The deposits are intermediate stages between a limestone and a flint. The limestones on these horizons are everywhere fossiliferous and, as would be expected, the flints contain the same fossils, although they are less abundant and less delicately preserved, with the possible exception of the *Fusulina* and other small types. The state of the fossils indicates alteration changes. The flint in local areas has a banded and orbicular structure which shows secondary arrangement of the matter. Replacements in many of these beds are evident, but it is uncertain how much is to be accredited to the early stages of formation and how much to the later.

Taking the third view next into consideration, the original rock is a regularly deposited limestone covered by later sediments. Circulating ground waters holding soluble silica and organic components in solution attack the limestone, taking calcium carbonate into solution and depositing silica in its place. The flints are thus of secondary origin. The chemical action involved is the same as it is in the second case, except that it is performed through the medium of circulating ground waters in place of salt brines. The change is effected under less favorable conditions, but the force is operative over a longer time interval. The action began with the covering of the bed by later sediments and is still effective. The question is whether the action of ground waters is sufficient to change thick beds of limestone extending over wide areas to strata of flint. On the Boggs horizon the flint is from a few inches to 1 foot 6 inches thick, and is rather local; on the Upper Mercer horizon the volume varies from 1 foot to more than 10 feet, and it is very persistent over a wide area, and on the Ferriferous horizon it varies from a few inches to 10 feet, and is often continuous for several miles. The variation in the character of these members is shown under the discussion of their stratigraphy.

The work of ground waters in effecting the solution of one component and the substitution of another is well known, and this action accounts for the nodules of flint in many of the massive limestone and chalk beds. It is a question, however, as to whether this accounts for the origin of the thick beds of flint in the coal formations of this area. Where the section was measured on the Lee Moore farm in Jefferson Township, Coshocton County, the lower layer is composed of irregular masses of relatively pure flint and limestone which are distinctly separated, but with the flint constituting the greater part. Replacement of calcium carbonate by silica is strongly suggested. Above his layer, there is 11 feet of thin to medium-bedded shaly limestone containing practically no flint, and directly overlying this shaly limestone

there are two layers of flint which are only slightly calcareous at most, and which contain no large irregular masses of limestone. If these two beds were originally limestone the transformation from limestone to flint has been quite complete. The series thus shows limestone beds lying between flint strata. If these flint beds were formed through the action of circulating waters on limestone, subsequent to the formation of the entire deposit, then the limestones occupying the middle of the deposit should also show evidence of the same influence, which is not the case. The structure of the deposit, therefore, seems to show that these rocks were laid down in about the same condition as that in which they are now found.

The succession of flint and limestone beds in the Pottsville and Allegheny formations of Muskingum County are of interest. The order and character of the members follow:

Hamden member, limestone, rarely flint or flinty.
Ferriferous member, flint, seldom limestone.
Putnam Hill member, limestone, only occasionally flinty.
Upper Mercer member, flint, locally limestone or part limestone.
Lower Mercer member, limestone, in places flinty.
Boggs member, flint, generally impure, locally limestone.
Poverty Run member, limestone, siliceous and ferruginous, but not flinty.

An exceptional feature about this series of rocks is that every alternate one is similar in composition, being either flint or limestone. If the transformation of limestone to flint took place through the action of ground waters, the question arises why all the beds were not similarly affected as they cover only a small interval and as such action extends to great depths. Further, the limestones on these horizons are similar in both physical and chemical properties.

The general character of the overlying strata of these separate beds is about the same, being shales, sandstones, clays, and coals; hence the action of ground waters on these limestones should not be materially different. The circulation of water through strata like plastic clay or carbonaceous shale, common coal formation rocks, is very slow and the action is therefore rather limited. If silica sufficient to produce a bed of flint several feet in thickness were drawn from the adjacent rocks, their depletion in this component should be noticed, but such an effect is not apparent. The small quantity of nodular flint in the Putnam Hill, and in the Lower Mercer members appears to be more nearly a measure of the action of circulating waters than does the large quantity of massive flint in the Upper Mercer and in the Ferriferous beds. Where the conditions are somewhat uniform, the action of the ground waters should be about the same also, but this is not the case. A thin bed may be all limestone; a thick bed may

be entirely flint; or the proportion of flint to limestone in the same bed may vary greatly in a short distance.

In conclusion, it appears that these flint beds were original deposits laid down in shallow water under conditions similar to those where limestones were deposited, but where siliceous material from organic life was present in considerable quantities, and was either deposited directly or was substituted for calcium carbonate of newly formed limestones. The action of ground waters in the silicification of limestones appears, therefore, relatively small; and this view is further strengthened by evidence afforded by higher beds in this county.

The coloration of the Upper Mercer flint is also worthy of consideration. The lower layer, which is the only one present in much of the area, is generally very dark or even black, whereas, the overlying layers in Coshocton and Perry counties are gray or mottled. However, even in the same stratum the color varies considerably, often changing in a few miles from a light shade to coal-black. Further, some of the blocks are often traversed by small veins of flint usually differing in color from the main body. The black coloration is largely due to iron oxide pigments, which are capable of forming a series of shades or colors depending upon the state of oxidation or hydration, and upon the quantity of these pigments present. Owing to the colloidal dispersion of the pigments, which exerts a maximum effect, the quantity of coloring matter is not necessarily large, even in the coal-black varieties of flint. Even if attenuated, however, these pigments may produce high coloration. A coloring agent of secondary importance is carbon; but it is not certain whether this carbon is derived from the reduction of limestone or directly from organic matter. The presence of coal beds often closely associated with flint is conclusive evidence of the existence of reducing conditions, which are favorable for the preservation of carbon. Argillaceous matter is the chief coloring agent in the gray varieties.

Economic Value of Upper Mercer Limestone and Flint

The economic worth of the Upper Mercer member must be considered for its flint and not for its limestone, as the latter is seldom present. The quantity of flint on this horizon varying from dark to coal-black is large, as the bed extends entirely across the county with but few wants. In fact, this black flint is far more abundant than the light flint of the Vanport or Ferriferous member which is so conspicuous on Flint Ridge and its lateral projections. The average thickness of the Upper Mercer bed in Muskingum County is about 1 foot 5 inches. It varies, however, from a few inches to as much as 5 feet. In local areas the bed is limestone or a mixture of this with flint. The limestone is bluish-gray to dark in color and somewhat siliceous in character. In fact, it closely resembles the Lower Mercer

in both appearance and composition. The flint varies in color from a light shade to coal-black and in composition from relatively pure silica to that decidedly calcareous or ferruginous.

The flint has but little economic value at present. It makes a good foundation for roads, but is not suitable for the top coating owing to the hardness of the material which readily scratches steel, and owing to the sharp edges developed in breaking, which cut the tires of automobiles and the hoofs of animals. Although the flint is very dense it is sufficiently brittle to be reduced with little difficulty. Large quantities of this material are readily available in many localities in the western part of the county often where roads are badly needed. It may be employed for decoration in residences and public buildings, as the material is weather resistant and very attractive. Some of the variegated and mottled varieties are beautiful. If crushed, it would make good material for sand blasting, which is now practised so largely for cleaning buildings, steel castings, etc.

UPPER MERCER ORE

The Upper Mercer ore, which is more generally known in southern Ohio by the name Big Red Block, or Franklin ore, lacks continuity in Muskingum County, as it was observed at only a few places. However, in these places the thickness of the deposit is about the same as it is in Jackson, Scioto, and Lawrence counties, where it was mined extensively for many years for iron smelting in the early charcoal furnaces. The measurements of the bed in Muskingum County vary from 3 to 6 inches. Its position is close to that of the Upper Mercer limestone or flint. In fact, in local areas the ore rests directly on the flint or limestone, whereas in other localities it is separated from this stratum by a bed of shale expanding from a few inches to several feet in thickness. The ore is often sparingly fossiliferous and the types present are about the same as those found in the underlying flint or limestone. In places the associated shales also bear impressions of the marine life that existed during this general period of deposition of ore, flint, and limestone. The member will be traced only in a general way, as the exposures are few and the value trifling. In a ravine just south of the flour mill at White Cottage the following relations between the Upper Mercer ore and Upper Mercer flint were noted:

	Ft.	In.
Shale	5	--
Ore, *Upper Mercer*	--	6
Shale	--	5
Flint, dark, *Upper Mercer*	1	5

On the land of J. W. Beam, in the western part of Section 20, Newton Township, the Upper Mercer ore lies directly on the Upper Mercer flint, and measures 6 inches in thickness. Along the road in the northern part of Section 28, Newton Township, the Upper Mercer

flint or limestone is absent. This condition, with only the ore present, was seldom observed in this county, although it is the characteristic arrangement in southern Ohio. Along the Licking River west of Zanesville, in Falls Township, the ore and flint appear either to be merged into one bed or the flint is very ferruginous and the ore wanting. The stratum is a mixture of flint and iron ore. This condition was noted at a number of places. On the land of J. Butler, 1½ miles north of Dillon Falls, the following structure was observed in a stream bed:

	Ft.	In.
Shale, gray	1	--
Ore, nodular, *Upper Mercer*	--	3
Shale	--	3
Flint, black, *Upper Mercer*	1	1

At another exposure near-by the ore measures 6 inches in thickness. Along the road in Section 12, Muskingum Township, east of Township Hall, the ore varies from 2 to 8 inches in thickness, and is separated from the underlying limestone by several feet of shale. In the eastern part of this township the Upper Mercer ore is absent, or is merged with the flint, the upper part of which is often very ferruginous. This is the general condition noted also in Hopewell, Licking, Cass, and Jackson townships.

The Upper Mercer ore was not utilized to any extent in Muskingum County, even during the days of the charcoal furnaces, as the deposits are local and the ore thickness small. It belongs to the siderite class of ores which is typical of the unweathered ores in the Pottsville rocks of Ohio. Along the outcrop of the bed chemical agencies have changed it from the carbonate to the hydrated oxide or to the limonite class. From general appearance the ore is somewhat siliceous, even where the bed is separated from the flint. It carries some lime and magnesia which, however, aid in smelting. The phosphorus content of the Pottsville ores usually fits them for the smelting of foundry iron. Owing to the limited quantity of the Upper Mercer ore in Muskingum County, and to the small demand for native ores, since the advent of the rich Lake ores, the bed has no value worthy of consideration at present.

TIONESTA OR NO. 3b COAL AND CLAY

Between the Upper Mercer limestone or flint and the Putnam Hill limestone, an interval of about 45 feet in Muskingum County, there are two well-defined coal horizons. The lower coal bed, which is generally thin, and in places wanting, but which carries a clay stratum more persistent than the coal, lies about midway between the two limestones, and from the position and association with respect to other strata it is the equivalent of the Tionesta or No. 3b coal of southern Ohio, where it has excellent volume in places. The clay on this horizon in Muskingum County has far more economic value than the

coal, as it is employed in a large way for ceramic purposes. The upper coal bed in this general interval lies either directly below the Putnam Hill limestone or is separated from it by only a few inches of shale. It is more persistent than the lower coal bed, but is less conspicuous in thickness and in quality. These beds are found above cover in all or parts of every township west of the Muskingum River except Harrison, and in parts of Wayne, Washington, Madison, and Adams east of this important stream. Owing to the uncertainty of the Tionesta coal and its associated clay these beds will be traced across the county only in a general way.

On the land of J. W. Beam, in Section 20, Newton Township, the Tionesta coal was well exposed for measurement along a stream bed where it has the thickness given below:

	Ft.	In.
Coal, *Tionesta*	--	11
Clay, siliceous	3	--
Covered	10	--
Ore, siliceous, *Upper Mercer*	--	6
Limestone, dark, flinty, *Upper Mercer*	--	9

The above record shows the position of the Tionesta coal with reference to the Upper Mercer limestone. The position of the Tionesta clay, mined quite extensively in the vicinity of Roseville for ceramic uses, is shown in the following record secured along the road in the southeastern part of Section 33, Newton Township:

	Ft.	In.
Limestone, *Putnam Hill*	1	--
Shale and covered	5	--
Sandstone, massive	26	--
Clay, part covered, *Tionesta*	4	--

The Tionesta coal in this locality is usually a mere stain lying above the clay, but in a few places north of this it thickens to as much as 1 foot. In Springfield Township both clay and coal on the Tionesta horizon are rather persistent, but the clay only has noteworthy volume.

Along the Dugway on Putnam Hill, Zanesville, both coal beds as well as the clays on this general horizon were well exposed for measurement, and the following record secured:

		Ft.	In.
Limestone, blocky	*Putnam Hill*	1	3
Limestone, irregular, flinty		1	11
Shale, black		--	2
Coal, somewhat bony, *Brookville*		--	9
Clay, lower part siliceous		7	2
Coal, bony	*Tionesta*	--	8
Coal, good		--	5
Clay, lower part siliceous		8	8

At this place the Tionesta coal is exceptionally close to the Putnam Hill limestone. The coal near the plant of the Zanesville Stone-

PLATE V.

A—A quarry in the Homewood sandstone west of Zanesville.

B—A quarry in the Clarion sandstone north of Zanesville.

ware Co. has a thickness of about 2 feet, and has been mined in a small way for local use. In places this coal bed and a part or all of the underlying clay have been replaced by the Homewood sandstone.

In Hopewell Township the interval from the Upper Mercer limestone or more often its flint to the Putnam Hill limestone is considerably below the average in thickness, but the Tionesta coal and also the coal directly below the Putnam Hill limestone are fairly constant, although usually very thin. The clays, however, are locally well developed and are of good quality. On the property of Harrison Drumm, in the western part of Section 14, this general interval contains the following rocks:

	Ft.	In.
Limestone, *Putnam Hill*	1	2
Shale	--	2
Coal, *Brookville*	--	1
Clay, light, siliceous	3	--
Sandstone, light, clay-bond	5	--
Clay, dark, flint } *Tionesta*	1	--
Clay, light, plastic } *Tionesta*	2	--

This is the only place in Muskingum County where a true flint clay was observed on this horizon. The Tionesta coal in the northern part of Hopewell Township is rather inconstant, and the associated clay is also absent, in many places.

In Falls Township the Tionesta coal is worthy of mention only for stratigraphic reasons. On the W. M. Burgess farm near Dillon Falls the coal is absent, but the clay is present in fair thickness. The section follows:

	Ft.	In.
Clay, light, *Tionesta*	3	--
Shale, gray	10	--
Covered	2	8
Flint, black, ferruginous, *Upper Mercer*	--	7

Along the Muskingum River in this township, the Tionesta clay has good volume and is of excellent quality. On the farm of W. L. Bunting, about 1 mile south of Drake, this clay is mined by stripping and delivered by the Wheeling & Lake Erie Railroad to the American Encaustic Tiling Co., and the Mosaic Tile Co., Zanesville. The average thickness of the bed is between 5 and 6 feet. The clay is light colored, plastic, and is quite free from siliceous matter and ore nodules.

In Muskingum County the Tionesta coal has its best development south of Zanesville, in Wayne Township, where the bed has been mined in a desultory way for many years for local use. The area is yet capable of furnishing considerable fuel as the bed outcrops near the base of the hills and as it has not been followed far under cover. The usual thickness of the coal is from 1 foot 8 inches to 2 feet 6 inches. The stratum is locally known as the White Ash coal, owing to the char-

acter of this component. The Tionesta coal outcrops along the bluff of the Muskingum River in the southern part of Zanesville, and there measures 1 foot 10 inches. On the Richardson property in Salt Gum Hollow, just south of Zanesville, this coal has been mined at several places by drifting. The coal is reported to hold its thickness very well. The structure of the bed at this place follows:

	Ft.	In.
Coal, *Tionesta*	2	5
Shale, bony	--	2
Clay, siliceous	3	--

A sample of the Tionesta coal was taken at this place for chemical analysis. The stratum lies 35 feet below the Lower Kittanning coal. Along Howards Lane, the next hollow south of Salt Gum, the coal is generally thin, varying from 1 foot to about 2 feet. No mines were noticed. The bed in this locality lies about 10 feet below the Putnam Hill limestone. The Tionesta clay, in part a clay-bond sandstone, is about 8 feet in thickness. In Washington Township the coal is usually wanting, but the clay is generally present in good volume. In places it thickens to as much as 5 or 6 feet, and is of good quality for ceramic work. This stratum, in many places, is overlain directly by the Brookville clay, which is of fair quality also.

In Muskingum Township the Tionesta coal expands somewhat, and the associated clay is often of excellent thickness and quality; in fact it is regularly mined for ceramic purposes at a number of places. Near the mouth of Blunt Run, this clay is mined by drifting on the land of Mrs. Ora Lane and shipped to the Ohio Pottery and to the Brush-McCoy Pottery at Zanesville. Just north of the above place, on the land of Joseph Moody, this clay is also mined by drifting for the Art Pottery Co., at Zanesville, and for the Guernsey Earthenware Co., at Cambridge. Tionesta clay, mined by drifting on the C. C. Crabtree farm, on Blunt Run, is shipped to the Roseville Pottery and the Zanesville Stoneware Co., Zanesville. In this locality the Tionesta coal is represented only by a smut streak or by a few inches of dark-colored clay. North of this, in Cass Township, the coal is somewhat constant, but seldom exceeds 1 foot in thickness.

The Tionesta coal, which in few places has a thickness of 1 foot, and its associated clay are present near the summits of the main ridges in eastern Jackson and eastern Licking townships, but neither has been utilized. No coal of value was found on this horizon in Madison and Adams townships, although the clay in many places has fair volume and purity. In local areas both beds are replaced by sandstone.

Economic Value

The Tionesta coal adds but little to the fuel resources of Muskingum County, as the most that may be expected of it is a small supply of

domestic fuel in a few localities. The most promising areas are near Zanesville, in Wayne and Springfield townships, where the bed often has sufficient thickness to be mined by drifting. In a few places in Newton, Hopewell, and Cass townships, small quantities of fuel may be obtained by stripping along stream beds.

The general character of the Tionesta coal is shown by the following analysis of a sample taken by R. E. Lamborn and the writer, on the Richardson property in Salt Gum Hollow, Wayne Township. A sample 12 by 5 inches was cut from the solid face of coal where it outcropped along a stream bed, but where the covering was 10 feet in thickness. The coal was very moist. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	65.31	Moisture	8.50
Hydrogen	5.49	Volatile matter	36.44
Oxygen	17.60	Fixed carbon	45.89
Nitrogen	1.13	Ash	9.17
Sulphur	1.30		
Ash	9.17		

Calorific value { 6,511 calories. / 11,720 B. t. u.

Air drying loss of moisture, 4 per cent.
Ash very refractory, not softened at 1,500° C.

The Tionesta coal is high in ash, which is clay-like in composition, light-colored, and powdery. It is very refractory, and gives no clinkers under ordinary conditions of firing. The heating value of this coal is low, owing partially to the moisture and ash content. It produces but little soot in burning. The sulphur content is lower than that of any other coal examined in Muskingum County. Not only is the Tionesta coal well suited for domestic purposes, but it has excellent properties for burning the better grades of ceramic ware where color of body or absence of sulphur blisters on glazes are desired. In the vicinity of Zanesville the clay, which has excellent volume and good ceramic properties, may be mined as an associated product with the coal, thus giving the necessary height for ease in working.

In Muskingum County the clay associated with the Tionesta coal is of more value than the coal itself and is far more constant. The average thickness of the clay is about 3 feet 6 inches, but measurements of 6 to 8 feet are not uncommon. Further, in many places the Tionesta clay is separated by only a thin stratum of shale or sandstone from the overlying Brookville clay, which has fair properties also. In places both beds may be mined conveniently from the same working for such uses as stoneware or building brick. The Tionesta clay at its best has excellent properties. It is very free from siliceous material and from

concretions of iron compounds. The plasticity is high, making it a good bonding clay, for which it is largely used in this district. The clay is easily blunged and is thus prepared for use. The fluxing impurities are moderate in amount; hence it has fair refractory qualities. It burns to a light-buff color and vitrifies to a strong body. Its burning range is wide and its shrinkage, both drying and burning, is not excessive for plastic clays.

Some of the general physical properties of the Tionesta clay from the Joseph Moody mine near Ellis, determined by H. G. Schurecht of the Bureau of Mines, are given below: The quantity of residue left on the 150-mesh screen after thorough blunging was only 2.5 per cent, which is exceptionally low. The apparent porosities of the burned ware are 19.38 per cent at Cone 01, 15.90 per cent at Cone 2, and 3.70 per cent at Cone 4; whereas the volume shrinkages are 13.20 per cent at Cone 01, 15.90 per cent at Cone 2, and 24.00 per cent at Cone 4. This clay has good mechanical strength in the dry state, being 389.5 pounds per square inch for the run-of-mine and 467.9 pounds per square inch for the washed material. The burning tests show that this clay becomes vitrified at Cone 4, which is an important property for both common and chemical stoneware. Its softening point is Cone 26+, which meets the requirements of a No. 3 fire clay as classified by Bleininger. The warpage under load is comparatively low at Cone 01 and Cone 2, but is high at Cone 4.

This clay was sampled by the writer and analyzed by Prof. D. J. Demorest, whose results are given below:

Silica, SiO_2	56.98
Alumina, Al_2O_3	26.22
Ferric oxide, Fe_2O_3	2.00
Lime, CaO	.60
Magnesia, MgO	.79
Titanic oxide, TiO_2	1.30
Sodium oxide, Na_2O	.20
Potassium oxide, K_2O	1.89
Loss on ignition	10.00
Total	99.98

The analysis shows about 26 per cent of free silica, yet this component is not apparent to the touch, as it is very finely divided. The low alumina with the 6.78 per cent of fluxes lowers the refractory qualities to that of a No. 3 fire clay; whereas its silica is considerably lower than that of a standard stoneware clay. Blended with other clays it is used extensively in the Zanesville district for stoneware and art pottery and for encaustic tiling. Further, it is shipped to some extent to outside points.

Another sample of Tionesta clay taken by the writer from the mine

of W. H. Brown and S. H. Sharkey, located about 1 mile west of Crooksville, gave the following results, as determined by H. G. Schurecht of the Bureau of Mines. The dry cross-breaking strength of this clay is only fair, the modulus of rupture of the run-of-mine clay being 178.8 pounds per square inch, and that of the washed clay being 314.9 pounds per square inch. It does not vitrify at Cone 4, but softens at Cone 28, which is similar to that of a No. 2 fire clay. It is not very resistant to warpage under load strain. The apparent porosities of the burned ware are 24.95 per cent at Cone 01, 22.95 per cent at Cone 2, and 17.80 per cent at Cone 4; whereas its volume shrinkages are 6.63 per cent at Cone 01, 8.32 per cent at Cone 2, and 11.35 per cent at Cone 4.

The analysis of the clay made by Prof. D. J. Demorest follows:

Silica, SiO_2	59.78
Alumina, Al_2O_3	23.79
Ferric oxide, Fe_2O_3	2.11
Lime, CaO	.85
Magnesia, MgO	.10
Titanic oxide, TiO_2	1.30
Sodium oxide, Na_2O	.23
Potassium oxide, K_2O	1.94
Loss on ignition	9.88
Total	99.98

The Tionesta clay forms a valuable addition to the ceramic assets of Muskingum County, as the quantity of material available is large, and as the clay is well fitted for many ceramic purposes.

HOMEWOOD OR TIONESTA SANDSTONE

The Homewood or Tionesta sandstone, which is considered by many to be the top of the Pottsville formation in Ohio, is well developed only in local areas in Muskingum County. The position usually assigned for this member is below the Brookville coal and above the Tionesta coal, but it often replaces not only these coals, but many feet of other rocks. The member is very irregularly bedded, and the deposits erratically distributed, but these conditions are to be expected as the material was laid down along the shore of an ancient sea. The thickness varies from a few feet to as much as 70 feet or even more. The lower surface is generally very irregular, often exhibiting a well-defined disconformity, an example of which is exposed along the Muskingum River at Putnam Hill, Zanesville. The irregularity of the upper surface of this sandstone is not so apparent and frequently the most noticeable feature is the absence of strata, which the sandstone has replaced. This sandstone often coalesces with other sandstones found higher or lower, so that the exact limits of the Homewood member are not only difficult, but frequently impossible to determine. In many places it joins with a sandstone lying above the Putnam Hill

limestone. The Homewood sandstone is seldom continuous for any great distance, but deposits of some thickness are found in every township except Harrison west of the Muskingum River, and in Wayne, Washington, Madison, and Adams east of this stream. Owing to the irregularity of the bed, and to its small economic value only a few sections showing the position of this sandstone need be given. Along the road in the southeastern part of Section 32, Newton Township, the following rocks were exposed for measurement:

	Ft.	In.
Limestone, *Putnam Hill*, blue, fossiliferous	1	--
Shale and covered	5	--
Sandstone, massive, *Homewood*	26	--
Clay, *Tionesta*	4	--

The Homewood sandstone in this locality is massive, light-yellow, owing to iron oxide pigments, and somewhat argillaceous. The deposit extends northward from this place along Moxahala Creek, but to the west and northwest it is unsteady. North of Darlington, in Section 11, this sandstone measuring 53 feet in thickness is cross-bedded, somewhat ferruginous, decidedly micaceous, light-colored, and loosely cemented. The deposit has good thickness in this locality, which is maintained as it extends eastward into Brush Creek Township and northward into Springfield. Along the road, in the northern part of Section 11, the upper 15 feet of the deposit is shaly; whereas the remainder is solid and massive, and was formerly quarried for building purposes. The thickness and character of the deposit are about the same in the vicinity of South Zanesville. In the western part of Springfield Township, the Homewood sandstone is not so well developed, but along the lower course of Brush Creek, in Brush Creek Township, the member is very prominent and retains its usual character. In parts of Hopewell Township it again attains excellent thickness, and along the road south of Mt. Sterling, in Section 2, measures 35 feet. West of this locality, the member is rather steady for several miles. It also appears along Poverty Run in the northern part of the township, where, in places, the bed measures as much as 50 feet in thickness.

Along the Muskingum River, in Falls Township, this sandstone also has fair continuity and thickness. The following section taken on the land of S. C. Hildreth, located about 1 mile north of the American Encaustic Tiling works, shows the general position and character of the deposit:

		Ft.	In.
Limestone, *Putnam Hill*		2	2
Shale, dark, with thin layers of coal, *Brookville*		--	7
Clay, siliceous		2	--
Sandstone, shaly		3	--
Sandstone, massive	*Homewood*	22	6
Sandstone, shaly		5	--

In the western part of the township, especially north of the Licking River, the Homewood sandstone is rather steady and has fair thickness. In Licking and Jackson townships this sandstone is due only on the high ridges in the eastern part. The bed is not prominently developed except in local districts. North of the Newark River Valley, in Jackson Township, the sandstone is not so well developed. However, it has good volume in local areas in the western part of Muskingum Township, but is thin or wanting in the eastern part. In Cass and Jefferson townships the member is seldom more than a thin bed of shaly sandstone. The sandstone is conspicuous along Blount Run in Washington Township, where it often replaces not only the Upper Mercer limestone, but the Putnam Hill as well. The rock is somewhat loosely cemented and in places the bed is broken by partings of shale. In the northern part of this township the sandstone is thin or absent, and the rocks in the interval are shales and clays. The bed seldom has good development in the southern part of Madison Township, but in the northern part it is more prominent in local areas. As a general thing, however, the sandstone is somewhat shaly and of no great thickness. The member is present along Wills Creek in Adams Township and its condition in that locality is about the same as in Madison Township.

Economic Value

For many years the Homewood sandstone was used, especially around Zanesville, Brighton, Putnam, and South Zanesville, for building stone, but at present it is only occasionally employed, as concrete is used instead. It was used principally for foundations, retaining walls, culverts, steps, walks, and other minor purposes. This sandstone occurs in massive ledges broken by irregular and widely spaced bedding planes and by vertical joints. It is somewhat cross-bedded, but shows little tendency to part on weathering along these planes. It is rather fine-grained for a coal formation sandstone. It is composed in the main of well-rounded quartz grains admixed with a noticeable quantity of mica flakes, and is bonded by argillaceous matter and iron oxides. The stone in the bed, or when freshly quarried, is rather soft, but it hardens on exposure to the atmosphere. The material is very resistant to weathering agencies, as is shown not only by the blocks and ledges exposed along the outcrop, but by the stone in walls and foundations which have been standing for many years. Although the rating of the Homewood sandstone at present is low compared to that of the Berea, yet its value for local purposes must be duly recognized.

CHAPTER III

ALLEGHENY FORMATION

The Allegheny formation is by far the most important division of rocks appearing at the surface in Muskingum County as it contains the beds of coal from which the fuel supply is largely drawn, and the thick deposits of clays and shales upon which many ceramic industries are built. Besides these it contains limestones, sandstones, flints, and iron ores of lesser value, but serving many useful purposes. In a general way this division of rocks caps the highest hills and ridges in the western part of the county, and dipping eastward and southward disappears in the eastern part along a line drawn from Bloomfield in Highland Township to Stone in Harrison Township. The Allegheny formation begins with the Brookville or No. 4 coal, which is poorly developed in this county, and ends with the Upper Freeport or No. 7 coal which has good thickness only in local areas. The total thickness of the formation is approximately 177 feet.

In this county the line of division of the Allegheny formation from the underlying Pottsville is purely arbitrary. Such a separation is not warranted by the lithological character of the rocks, by a basal disconformity, or even by paleontological evidence. The main difference lies in the fact that the coal beds in the Allegheny formation are better developed than those in the Pottsville.

The separation of the Allegheny from the Conemaugh formation, which lies higher in the geological column, is based on more definite evidence. The Upper Freeport or No. 7 coal is the last thick coal deposit found in the rock column for about 377 feet, or until the great Pittsburgh bed is reached. The shales below the horizon of the Upper Freeport coal gradate not sharply, but yet in a short distance from those generally gray and somewhat siliceous to those above the coal bed, which are often clay-like in composition and frequently highly colored with iron oxide. Further, the shales above this coal are much more calcareous than those below it. The Upper Freeport coal marks in a general way the surface above which fresh-water limestones were deposited in abundance. The separation of the rocks into the two formations, however, is based primarily upon lithological evidence. The base of the Mahoning sandstone, the position of which is just above the Upper Freeport coal, is considered the plane of separation, but the disconformity here is no more pronounced than it is at the base of other sandstones lying within the formations. Moreover, in large areas the Mahoning sandstone is absent, and its place is taken by shales showing

no break in deposition. No sudden change in the marine life is apparent, as the elimination of some forms and the introduction of others is gradual.

The Allegheny formation is subdivided into members, the most important of which are the Brookville coal, Putnam Hill limestone, Clarion coal, Ferriferous or Vanport limestone, Lower Kittanning coal and clay, Hamden limestone, Middle Kittanning coal and clay, Lower Freeport coal, and Upper Freeport coal. These members, with other minor divisions, will be taken up in regular order beginning with the oldest.

BROOKVILLE OR NO. 4 COAL AND CLAY

In former reports of this Survey the coal stratum just below the Putnam Hill limestone, or, as it is more frequently called, the Gray limestone, is known as the Brookville or No. 4 coal. Orton states:[1]

> A question must be admitted as to the equivalence of the Brookville coal of Pennsylvania with the Gray Limestone coal or Coal No. 4 of Newberry, from the fact that no limestone is reported in the Pennsylvania sections as accompanying the former seam; but the Gray Limestone coal of Stark County holds the exact place and relations of the Brookville coal. If the two coals are not one and the same seam, then the Brookville coal has no representative in Ohio and the Gray Limestone coal is without representation in Pennsylvania, a conclusion that no one acquainted with the demonstrable continuity of the remaining seams of the series will be prepared to admit.
>
> It will be remembered that the Putnam Hill limestone (Gray Limestone) dies out in Mahoning County as it is followed eastward, and in Perry County, as it is followed southward. Its horizon can be followed with certainty to the southward, after the limestone has disappeared, but the drift-covered region in which the limestone terminates at the eastward is less favorable for geological examination, and no better proof of the continuity of the horizon can be furnished than that given in Chapter 1. The facts there detailed certainly give a high degree of probability to the conclusion that the Brookville coal in its westward passage takes a limestone roof, and becomes Newberry's Coal No. 4 of Stark County.
>
> This seam is at its best in Stark County. It is struck in the northeastern quarter of the county in several small mines, but it is on the western side that it attains its largest development. * * * The seams show a maximum thickness of 6 feet. It is fairly steady, and a part of the seam is of good quality. * * * The Putnam Hill limestone makes its roof, resting in many instances directly upon the coal.
>
> Throughout Tuscarawas and Coshocton counties, the seam is generally thin, and no considerable mines have anywhere been opened in it, but in Newcastle, Bedford, and Jefferson townships of the latter county, the seam reaches a maximum of 4 feet and is opened in many country banks. * * * In Holmes County also, there are several neighborhood mines opened in the seam. * * * In Perry County and also in Hocking the seam is not worked, so far as known, but though thin it is universally present as far as the limestone extends.
>
> In Vinton County it again acquires mineable thickness, and it is quite largely worked for local supply in the vicinity of McArthur, where it is known as the Winters coal. It rises to 4 feet in thickness, and its quality is fair. It is associated with beds of flint in some parts of the county, and at several points it has a flint parting in the middle of the coal. From the latter fact it is known as the Flint Vein in a portion of the county.

[1]Geol. Survey Ohio., Vol. V, pp. 160-162.

the area. As a general thing the coal lies directly below the Putnam Hill limestone, but in some localities the two members are separated by a stratum of shale, seldom expanding to more than 1 foot in thickness. The coal is not as persistent as the limestone, for in local areas the place of the coal and also its associated clay is taken by shales, which are somewhat calcareous and usually very fossiliferous. The average thickness of the Brookville coal in Muskingum County is only about 3 inches. The measurements, however, vary from less than 1 inch to as much as 2 feet 6 inches. In character it changes from a bright bituminous coal to bone coal and even to carbonaceous shale. The Brookville coal and its associated clay are present above drainage in all the townships except Harrison, west of the Muskingum River, and in Wayne, Washington, Madison, and Adams townships east of this stream. Owing to the fact that this coal and its related clay have so little economic value in most of Muskingum County, and that many sections showing the position and character of these beds have already been given in connection with the stratigraphy of other members, they will be treated only in a general way.

The Brookville coal and clay are present above drainage in most of Newton Township. The beds lie well up in the hills in the western part, but owing to the dip of the rocks to the east and south they pass below drainage along Moxahala Creek in the eastern part. The coal is found just below the Putnam Hill limestone, but is seldom more than a few inches in thickness. The clay, however, has fair volume and varies from 2 to 5 feet in thickness. Along Salt and Kent runs, in the northwestern part of Newton Township, the Brookville coal and clay are locally replaced by shales, which are usually very fossiliferous. This condition was also noted west of this locality in Perry County.

In Clay Township, the Brookville members are found above drainage only in the vicinity of Roseville; whereas in Brush Creek Township they are present along the Muskingum River and along the lower course of Brush Creek. However, neither coal nor clay is of special importance. The Brookville members in Wayne Township are exposed only along the valley of the Muskingum River. The coal is generally thin, but the clay has fair thickness. In Springfield Township these beds present no new features, although they are well exposed at many places along the courses of all the larger streams. The section taken at Putnam Hill, and given below, shows them at about their maximum development in this area.

	Ft.	In.
Limestone, *Putnam Hill*	3	2
Shale, black	--	2
Coal, somewhat bony, *Brookville*	--	9

System	Formation	Thickness in feet	Member	General description	Thickness Ft.	Thickness In.
PENNSYLVANIAN	ALLEGHENY	177±	UPPER FREEPORT or No. 7.	Coal, locally present	2	6
				Clay, siliceous	5	--
				Shale, gray	1	--
			UPPER FREEPORT.	Limestone, nodular, non-fossiliferous	--	9
				Clay and shale	2	--
				Coal and carbonaceous shale	--	3
			BOLIVAR.	Clay, part flinty, locally very thick	4	6
			UPPER FREEPORT.	Sandstone, locally present	20	--
				Shale, gray, siliceous	10	--
			LOWER FREEPORT or No. 6a.	Coal, locally fair thickness	--	6
				Clay and shale	5	6
			LOWER FREEPORT.	Limestone, nodular, non-fossiliferous, locally present	--	6
				Clay and clay shale	2	3
			LOWER FREEPORT.	Sandstone, unsteady	25	--
				Shale	12	
			MIDDLE KITTANNING or No. 6.	Coal, bony Coal, good Clay shale Coal, good — Persistent	-- 2 -- 1	7 -- 1½ 1
				Clay, siliceous, plastic	4	--
				Shale and sandstone	9	--
			RED KIDNEY.	Ore, seldom present	--	3
				Shale, gray	2	--
				Coal, thin, usually only soot streak	--	1
			OAK HILL.	Clay, flint and plastic	4	8
			HAMDEN.	Limestone, fossiliferous, dark, ferruginous, often nodular, persistent	1	--
				Shale, argillaceous	2	--
			LOWER KITTANNING or No. 5.	Coal, locally developed	3	--
			LOWER KITTANNING.	Clay, light, plastic	6	--
				Shale or sandstone	3	3
			FERRIFEROUS.	Ore, locally present, nodular	--	3
			FERRIFEROUS or VANPORT.	Limestone, or flint, fossiliferous	2	6
				Limestone, shaly, fossiliferous	6	--
			CLARION or No. 4a.	Coal, bony Shale Coal Shale, pyritiferous Coal — Locally present	-- -- 4 -- 1	8 2 -- 6 10
				Clay, siliceous	2	4
			CLARION.	Sandstone, locally developed	24	6
			PUTNAM HILL.	Limestone, steady, fossiliferous	3	--

		Ft.	In.
Clay, lower part siliceous		7	2
Coal, bony	*Tionesta*	--	8
Coal, good		--	5
Clay		8	8

The Brookville coal and its associated clay are well above drainage in Falls and Muskingum townships. The coal stratum is worthy of attention only for its stratigraphic features as it is everywhere thin and impure. The clay, however, varies from 3 to 5 feet in thickness and has fair ceramic properties. The Putnam Hill limestone forms the roof of the coal bed. West of this, in Hopewell Township, these members are present along the main ridges. The coal lacks volume and purity, but the clay averages about 3 feet in thickness. The general features of the Brookville members are about the same in Licking and Jackson townships where the areas are relatively small, and where they are confined to the high ridges and knobs in the eastern parts. There is a slight thickening of the coal in local areas in Cass Township where the member is present along the main ridges. The coal and clay are present above drainage along the valley of the Muskingum River and along the lower courses of its larger tributaries in Washington Township. The average thickness of the coal is only about 4 inches, but that of the clay is from 4 to 7 feet. In its extension northward into Madison Township, the coal thickens somewhat; whereas the associated clay retains about the same volume and purity.

At Symmes Ford the coal is only 8 inches in thickness, but the clay has exceptional volume, measuring 12 feet 8 inches. Along the lower course of Symmes Creek the coal varies from 4 to 12 inches in thickness and the clay from 3 to 7 feet. Farther up this stream, however, the coal thickens locally, and for some distance along this creek, above the crossroads, the same thickness of coal is maintained. In small areas, however, it expands to as much as 2 feet 6 inches. In few places in the northern part of Washington Township is the Brookville coal more than 1 foot thick, but the clay averages nearly 4 feet. Along Wills Creek, in Adams Township, the coal and clay and the overlying Putnam Hill limestone are usually replaced by the massive Clarion sandstone. No good exposures of the coal or its associated clay were observed in northern Adams Township, as they are absent in part of the area and along the valley are deeply covered. The small areas in the northern part of the county, where the Brookville coal has fair volume, appear to be only outliers of the larger fields extending from Coshocton County to Tuscarawas County and then to Stark County, where the member reaches its greatest thickness in Ohio.

Economic Value of Brookville Coal and Clay

The Brookville coal in Muskingum County, excepting the small areas in Madison and Adams townships, has no value worthy of con-

sideration. The bed is not only thin, seldom expanding to 1 foot in thickness, but it is impure, usually tending towards a bony cannel coal. The most that may be expected from this member is small quantities of fuel obtained along streams. However, in local areas in Madison and Adams townships, the coal has sufficient thickness to be mined by drifting and when the thicker coal is exhausted it may be drawn upon for a local supply.

In Muskingum County, the clay on the Brookville horizon is of more value than the coal. The bed averages approximately 3 feet 6 inches in thickness. It often expands to 6 feet or more and in places it is separated from the Tionesta clay by only a few feet of shale or sandstone, so that both beds, if mined by stripping, may be readily obtained at a low cost. The conditions are favorable also for drift mining as the overlying Putnam Hill limestone forms an excellent roof. The clay is plastic, somewhat siliceous, and rather free from concretions of iron ore, silica, and pyrite. It vitrifies early, but forms a good dense body with a buff color. The Brookville clay is inferior to the Tionesta clay, but it may be used satisfactorily for such products as building brick, fireproofing, and stoneware.

PUTNAM HILL LIMESTONE

Stratigraphy and Extent

Next to the Lower Mercer the Putnam Hill is not only the best developed but is the most persistent limestone member in the coal formations of Muskingum County, as the bed extends almost continuously across the western half of the area. It occurs above drainage in Clay, Newton, Brush Creek, Wayne, Springfield, Hopewell, Falls, Washington, Muskingum, Licking, Jackson, Cass, Jefferson, Madison, and Adams townships, although in some of these localities it is present only in small areas. The Putnam Hill limestone lies just above the Brookville coal. Its position, however, is best referred to that of the Middle Kittanning coal, or to that of the Lower Mercer limestone, both of which are well developed in this county. The interval from the Putnam Hill limestone to the Middle Kittanning coal varies from 50 to 110 feet, but it is on the average about 80 feet; whereas the interval to the Lower Mercer limestone ranges from 45 to 95 feet, but is usually approximately 70 feet. The thickness of the bed varies from 6 inches to 6 feet, but the average from 112 measurements is 3 feet.

The Putnam Hill is a hard, dense, gray limestone, which from general appearance may easily be mistaken for the Ferriferous limestone of southern Ohio. In fact, both beds were often designated by former geologists "Gray limestone". It is somewhat lighter in color than the Lower Mercer limestone and slightly darker than the Ferriferous rock. Further, the Putnam Hill limestone closely resembles the Upper Mercer where this stratum has characteristic development.

It occasionally contains irregular masses of flint, indiscriminately placed, or irregular layers of flint rarely more than a few inches in thickness. In respect to its content of flint it differs widely from the Ferriferous and Upper Mercer members, which are generally flint or flinty, but resembles the Lower Mercer bed, which only in places contains this material. When the Putnam Hill limestone is thin it is generally argillaceous and siliceous in character and of a dark-blue color, much resembling the Lower Mercer rock. It is seldom distinctly ferruginous and is rarely associated with beds of iron ore. This limestone everywhere in the area exposed is fossiliferous, and in many places it contains a profusion of *Fusulina* and *Chonetes*, as well as other types in a less degree. The deposit is usually in one layer without well-defined partings or even bedding planes. In a few localities, however, the upper part of the member is somewhat shaly, and is distinctly separated, where it has been affected by weathering agencies along the outcrop, from the lower part which is massive in character.

Next to the Lower Mercer the Putnam Hill limestone is the best bench for geological reference in the lower coal formations of this county. It lies about midway between the Lower Mercer limestone and the Middle Kittanning coal, and is thus favorably placed for determining the stratigraphy of many uncertain and poorly developed beds in this interval.

The Putnam Hill limestone is readily traced northward and eastward from Muskingum County through Coshocton, Tuscarawas, and Holmes into Stark County, where it has excellent thickness. Northeast from Stark the limestone thins or disappears, but its position is carried across Mahoning County into Pennsylvania by the aid of the Brookville coal, which has good thickness and continuity. Its extension southward from Muskingum County is more limited, for the bed as a well-defined limestone stratum disappears in Perry County. The general horizon of this member, however, may be traced from Perry County through Hocking, Vinton, Jackson, and Lawrence counties to the Ohio River by beds of fossiliferous shale, impure limestone, carbonate iron ore, and calcareous flint. So far it has not been determined with which of these the Putnam Hill limestone is directly correlative. This limestone will now be traced rather carefully across Muskingum County.

Clay Township.—In Clay Township the Putnam Hill limestone is present above drainage only along the valley of Moxahala Creek near Roseville. The bed is about 2 feet in thickness, rather dark-colored, somewhat siliceous, and moderately fossiliferous.

Brush Creek Township.—The exposures of Putnam Hill limestone in Brush Creek Township are confined to the valley of Brush Creek and the lower courses of its tributaries from near Stovertown to the

Muskingum River. The thickness of the bed varies from 1 foot 6 inches to 2 feet 8 inches, and its position is from 65 to 80 feet below the Middle Kittanning coal.

Newton Township.—The horizon of the Putnam Hill limestone is above cover along all the larger streams in Newton Township. In the eastern part it is not far above drainage level, but, owing to the rise of the strata to the west, it lies well up in the hills along the western boundary. Although steady the bed in the western and southern parts of the area is generally thin, seldom exceeding 1 foot 8 inches in thickness. In local areas in the northeastern part of the township, however, it measures from 3 to 5 feet. The usual interval from this limestone to the Middle Kittanning coal is from 65 to 85 feet. In the northeastern part of Section 35 the following rocks were measured:

	Ft.	In.
Coal, *Middle Kittanning*	2	6
Clay	1	6
Sandstone	3	--
Clay, somewhat shaly	5	--
Clay, sandstone, and covered	70	--
Limestone, *Putnam Hill*	1	4

In Section 26 this member measures approximately 1 foot 6 inches in thickness, and in sections 27 and 28 it is often slightly greater than this, but the thickness of the bed is seldom more than 1 foot along Buckeye Fork in the southwestern part of the township. In the northwestern part fossiliferous shales are often associated with the limestone, and these shales are similar in many respects to those exposed on Putnam Hill.

The fossiliferous shales associated with the Putnam Hill limestone in this township are very similar to those occurring with the Black flint and ore in Vinton and Jackson counties. Fossiliferous shales were also observed on the Putnam Hill horizon in local areas in eastern Perry County. At present, however, the fossils have not been studied as an aid in the correlation of the beds. In the vicinity of Fultonham and White Cottage the Putnam Hill limestone is thin and often wanting. It has excellent thickness, however, in local areas in the northeastern part of the township in the vicinity of Darlington. North of this village in Section 11, this limestone measures 3 feet 6 inches in thickness, but near South Zanesville, in Section 1, the bed is considerably thinner, and varies from 1 foot 6 inches to 2 feet.

Wayne Township.—In Wayne Township the area of Putnam Hill limestone above drainage is small as it is confined to the valley of the Muskingum River, from Zanesville southeast to Section 10, and to the lower courses of its larger tributaries within this boundary. Owing to the depth of covering along the valley the limestone is seldom exposed

for observation except near Zanesville and in what are known as Salt Gum and Howards Lane hollows. The usual thickness of the stratum is between 2 and 3 feet.

Springfield Township.—The Putnam Hill limestone is only moderately persistent in Springfield Township, and it has its best thickness in the eastern part. The bed is above drainage along the courses of all the larger streams and is about 70 feet above the Muskingum River at Zanesville. The limestone, where thick, is of the usual light bluish-gray color, and is relatively pure, but where the deposit is thin it is of a very dark-blue or nearly black color, and is high in argillaceous and siliceous material. The bed is everywhere fossiliferous, and in local areas the associated shales also contain well-preserved forms.

The following section, taken on Putnam Hill at Zanesville, shows good development of Putnam Hill limestone, and also its relation to other beds of importance:

	Ft.	In.
Shale	10	--
Coal blossom, *Middle Kittanning*	2	--
Clay, shale, and covered	42	--
Shale with thin sandstone layers	14	6
Shale, gray	43	--
Limestone, blocky	1	3
Limestone, flinty — *Putnam Hill*	1	11
Shale, black	--	2
Coal, somewhat bony, *Brookville*	--	9
Clay, lower part siliceous	7	2
Coal, bony	--	8
Coal, good — *Tionesta*	--	5
Clay	8	8
Covered	22	--
Coal and bone shale	--	4
Clay and shale	7	10
Sandstone, shaly	6	5
Coal	--	1
Clay shale, siliceous	5	6
Sandstone, shaly	3	6
Shale, gray	4	5
Covered	5	9
Ore, *Lower Mercer*	--	3
Shale, dark	1	9
Limestone	1	2
Shale — *Lower Mercer*	--	2
Limestone	1	9

The general thickness of the Putnam Hill member shown above remains the same for about 3 miles west and south of this place, but beyond this the bed thins to 1 foot or even less. Further, in local areas, it is absent. On the property of W. G. Rehl, in Section 2, this limestone measures 3 feet in thickness, and is 86 feet below the Middle Kittanning coal. West of this in Section 3, on the farm of J. Rehl,

the bed has about the same thickness, has been quarried, and the material crushed for agricultural purposes. In the western part of the township the bed is thin, varying from 6 inches to 1 foot 6 inches in thickness and the stone is of poor quality. Along the road in the southwestern part of Section 8 the carbonate ore above the Putnam Hill limestone contains a profusion of small gastropods excellently well preserved. This bed is very local in extent and lies in the gray shales, which in many places in Muskingum County are very fossiliferous. The stratigraphic position of this iron ore is much the same as that of a limestone stratum which appears above the main bed of the Putnam Hill member in local areas in Madison and Jackson townships. The limestone shown in this locality is thin and nodular.

Hopewell Township.—The Putnam Hill limestone is above drainage in all of Hopewell Township where it is found high on the main ridges and spurs. The bed has excellent volume in local areas, the largest of which are south of Mt. Sterling in sections 1, 2, 11, and 12, north of this village in sections 11, 12, 19, and 20, and in the northern part of the township in sections 3, 4, and 5. In these places the deposits vary from 2 to 6 feet in thickness and the stone is relatively pure. In the remainder of the township the bed is generally thin and occasionally absent, and the limestone is more siliceous and argillaceous.

On land of Jesse George the Putnam Hill limestone measures 4 feet in thickness, and on the property of Margaret Redding, in Section 12, 4 feet 6 inches. North in Section 1, also on the Redding land, the thickness is 3 feet 10 inches. In the southern part of Section 22 this limestone has been quarried and ground for agricultural purposes on the farm of W. P. Burley. The bed measures 4 feet 7 inches in thickness and the stone is of excellent quality. In the central part of Section 2 the Putnam Hill limestone, where well exposed along the road, measures 2 feet in thickness, and lies 68 feet above the Lower Mercer limestone. It is overlain by 42 feet of gray, siliceous shale, very similar to that exposed at Putnam Hill near Zanesville. In the western part of this southern extension of Hopewell Township the Putnam Hill limestone is generally thin, but moderately steady. The thickness of the bed varies from 6 inches to 1 foot 6 inches, but averages about 1 foot. This is the condition of the member also south of Flint Ridge and north of the National Road. However, in the eastern part of the township east of Poverty Run, the limestone in local areas measures as much as 3 feet in thickness. In Section 19, on the property of Norton Dove, the limestone, 3 feet thick, lies 28 feet above the Bedford coal, 48 feet below the Hamden limestone, and 80 feet below the Middle Kittanning coal. The thickness of the bed is about the same in Section 11, but it thins considerably in the sections west and north of this. Along the western tributaries of Poverty Run this limestone is generally thin, seldom measuring more than 1 foot 6 inches in thickness, but along the

northern extension of Flint Ridge in sections 3, 4, and 5 the stratum in local areas has excellent thickness. On the farm of Fred Cromer, in Section 3, the Putnam Hill limestone is 3 feet or more in thickness and lies near the summit of the ridge. Along the ridge in the eastern part of Section 4 the thickness of the deposit is 4 feet, but in the northern part it expands to 6 feet. At this place the Putnam Hill limestone lies unusually near the flinty limestone, a phase of the Ferriferous member, and it almost reaches the maximum thickness for Muskingum County. The stone is very fossiliferous, and is rather pure, as it is especially free from flint or chert. It is dense and massive and of the characteristic light, bluish-gray color. On the whole this limestone in Hopewell Township is moderately persistent, but is erratic in thickness, changing in a short distance from a few inches to from 3 to 6 feet.

Falls Township.—The Putnam Hill limestone is almost continuous across Falls Township, but the bed is variable in thickness and in composition. It lies above drainage in the entire area, being about 70 feet above the bed of the Muskingum River at Zanesville, and near the summits of the high ridges near the Sodom School in the northwestern part, where it reaches its greatest thickness, from 3 to 5 feet.

Along Timber Run, about 1 mile west of Zanesville, on the farm of Charles Grimm, the Putnam Hill limestone measures 1 foot 6 inches, and has about the same thickness north of this along the Licking River, also to the west. Near Dillon Falls the stratum varies from 1 foot 6 inches to 4 feet 6 inches in thickness, and is usually overlain by shales similar to those exposed at Putnam Hill.

In the vicinity of the Sodom School the Putnam Hill is a gray, fossiliferous, rather pure limestone, and is massive in character, being very similar in appearance to the Ferriferous limestone of southern Ohio. Along the Muskingum River north of Zanesville the stratum varies from 1 to 4 feet in thickness, but averages about 2 feet 6 inches. It lies from 70 to 80 feet below the Middle Kittanning coal and from 40 to 50 feet above the Upper Mercer flint or limestone.

Washington Township.—The area of Putnam Hill limestone above drainage in Washington Township is confined to the valley of the Muskingum River and to the lower courses of its larger tributaries. In places the bed is replaced by the massive Clarion sandstone that outcrops so prominently along the river from Zanesville to Gilbert. Near the Ellis Dam the stratum measures 4 feet 6 inches in thickness and lies 50 feet above the Upper Mercer limestone and flint. The limestone has exceptional thickness along the small stream in the northern part of this township where it measures 6 feet 2 inches. At this place the limestone is light-gray in color, quite free from nodules of flint, and massive in character. The overlying fossiliferous shale is well exposed along the stream bed.

Muskingum Township.—The Putnam Hill limestone is above

drainage in all of Muskingum Township. It lies near the summits of the main ridges in the western part, but owing to the general dip of the rocks to the east it lies about half way down the slopes of the hills in the eastern part. The bed has excellent continuity, except in local areas, where it is replaced by sandstone. In the eastern half of the area the thickness of the stratum is noteworthy as it varies between 3 and 6 feet and averages more than 4 feet. In many places the outcrop of the member is conspicuous along the courses of the streams. In the western half of the township the limestone is much thinner, and averages less than 2 feet. Along Blunt Run, in the southeastern part of this area, the bed is from 3 to 5 feet in thickness. The limestone is overlain by gray shales which, as previously shown, form a rather persistent covering in Muskingum County. The member has excellent thickness in its extension northward along the Muskingum Valley. At some places along Beech Run the bed is more than 5 feet thick. Along the Muskingum River above Rock Cut several measurements of the bed show that the thickness is from 4 to 6 feet, and along the small stream north of the Sandy Ridge School the thickness is approximately the same. Near the forks of the road just north of Section 11, on the land of Dennis Mattingly, the limestone measures 3 feet 6 inches. The usual thickness of the limestone in sections 12 and 13 is from 3 to 4 feet, but west and south of this it thins perceptibly, and along the road in the northern part of Section 3 measures only 1 foot 2 inches.

Licking Township.—Owing to the normal rise of the rocks to the west, and to the general lowering of the hills through the action of the preglacial streams, the areas of Putnam Hill limestone in Licking Township are small, being confined to a few ridges and high knobs in the southwestern and northeastern parts. On the extension of Flint Ridge into this township, northeast of the village of Cottage Hill, the limestone is from 4 to 6 feet in thickness, and lies only a short distance below the flint beds of the Ferriferous member. It is a gray limestone of good quality. On the ridges in the northeastern part of the township this limestone is generally thin, measuring from 1 to 2 feet, and in some localities it is replaced by sandstone.

Jackson Township.—In Jackson Township the Putnam Hill limestone is confined to the high ridges in the northeastern and southern parts. Although the areas of limestone are relatively small the thickness of the bed is excellent, and it averages about 4 feet. Along Graham Ridge the general thickness of the member varies from 4 to 5 feet and the quality of the stone is very good. It is highly fossiliferous, and *Fusulina* are especially abundant. Further, the thickness of the bed is maintained as it extends northward into Coshocton County.

Cass Township.—The Putnam Hill limestone is above drainage in all of Cass Township and occurs well up on the slopes of the hills and ridges. The bed has excellent continuity, but it is variable in thickness,

and it often changes in a short distance from a few inches to 4, 5, or even 6 feet. It is everywhere very fossiliferous and of the usual lithological character. In this township the limestone is best developed on the main ridge, which extends westward from Dresden, and is known as the Highlands. In the southeastern part of this township the limestone usually has good thickness, and the bed varies from 2 to 5 feet. Just west of Dresden the limestone is well exposed a'ong the road and measures 2 feet in thickness. About 1 mile south of the Elberson School the thickness of the bed, where exposed for measurement, is from 2 to 4 feet, but north on the main ridge, on land of H. Pepper, the thickness is 6 feet, the greatest observed in this township.

In Section 13 the measurement of the bed is about 5 feet on the average, but near the Dutch School it is much thinner, occasionally less than 1 foot. Farther west, however, it again expands. On the ridges north of Shannon this stratum where observed is from 1 to 3 feet thick. Along Irish Ridge north of the preglacial Newark River Valley the limestone is very persistent and has excellent thickness. In Section 5 the measurement is from 3 to 6 feet with an average of more than 4 feet. The limestone is present also on some of the hills and knobs east of Little Wakatomika Creek and north of the Muskingum River. The following section taken along the road just north of Adams Mills shows the general stratigraphy of the limestone in this locality:

	Ft.	In.
Coal blossom, *Middle Kittanning*	3	--
Clay and covered	32	-
Shale	23	--
Limestone, *Putnam Hill*	3	--
Clay and covered	21	--
Shale, part covered	23	--
Flint, black, *Upper Mercer*	--	8
Shale and covered	1	--
Coal blossom, *Bedford*	1	--

Jefferson Township.—But little needs be said concerning the Putnam Hill limestone in Jefferson Township as the area is confined to a few hills. The thickness of the bed is usually between 2 and 4 feet.

Madison Township.—In Madison Township the Putnam Hill limestone is exposed along the valley of the Muskingum River and along that of Symmes Creek and its main tributary, North Fork. The average thickness of the member, from 15 measurements taken at various places in the area, is 4 feet 3 inches, and the maximum observed is about 6 feet. The overlying shales are often fossiliferous. Further, a second bench of limestone lying from 4 to 15 feet above the main stratum occasionally appears. This limestone may also be considered a part of the Putnam Hill, as both beds were deposited under somewhat similar conditions and are separated only by shale, which in places is calcareous. They are much alike also in composition and

appearance. In a few areas the Putnam Hill limestone is replaced by the massive Clarion sandstone which is very conspicuous along Symmes Creek in the central part of the township, and along the Muskingum River in the northern part. On the land of Mrs. Agnes Compton the main stratum of the Putnam Hill member is 4 feet 3 inches in thickness and the second bed is approximately 1 foot. The two layers are separated by 11 feet of shale.

On Symmes Creek the Putnam Hill limestone lies on the average approximately 76 feet below the Middle Kittanning coal. The general thickness of the limestone is between 4 and 5 feet and these measurements are retained farther up Symmes Creek and North Fork. In the hills east of Dresden the member also has excellent thickness and quality. In the northeastern part of the township the bed is locally wanting, being replaced by the Clarion sandstone.

Adams Township.—Owing to the dip of the rocks to the east, the Putnam Hill limestone in Adams Township is above cover only in the northwestern part along the valley of Wills Creek. The stratum has fair thickness and is of the usual lithological character.

This bed was not seen in Monroe Township although it is near drainage level along the lower course of White Eyes Creek.

Economic Value of the Putnam Hill Limestone

The Putnam Hill limestone forms a noteworthy addition to the mineral resources of Muskingum County and has long been employed for various uses. The bed is widely distributed and extends in a general way across the western half of the county. The mean thickness of the stratum from 12 measurements is 3 feet; although the thickness exceeds 5 feet in local districts which embrace several square miles. If all is available such a bed 5 feet thick will yield more than 18,000 tons of limestone per acre, or enough to build approximately 6 miles of standard 16-foot macadam road. Unlike the Upper Mercer and Ferriferous members, the Putnam Hill limestone in this county is never completely replaced by flint, although in local areas it contains flint, either scattered promiscuously throughout the bed or deposited along definite zones, but on the whole the stratum is rather free from such impurities. The general quality of this limestone is shown by the following analysis made by Prof. D. J. Demorest of a sample taken from an exposure on Beech Run:

Calcium carbonate, $CaCO_3$	92.32
Magnesium carbonate, $MgCO_3$	2.04
Silica, SiO_2	2.25
Alumina, Al_2O_3	.97
Ferric oxide, Fe_2O_3	1.10
Titanic oxide, TiO_2	.05
Phosphorus pentoxide, P_2O_5	.07
Sulphur, S	.16

This analysis shows that the composition of the Putnam Hill limestone is well within the limits demanded for the manufacture of Portland cement. The most favorable localities for the establishment of such an industry is where the bed has good volume and outcrops near the summits of the ridges, so that the limestone may be obtained by stripping. Further, the shale that lies just above the limestone is suitable for the silica and alumina components of the cement. The quantity of limestone used per year by a 1,500-barrel cement mill is approximately 108,000 tons or that produced on 6 acres where the bed is 5 feet in thickness, and the material is all available by stripping. To last such a plant 40 years the total area required is 240 acres.

The tests of the Putnam Hill limestone made by the State Highway Department, and given in this bulletin on page 40, show that the rock is above the average Ohio limestone for road building as it ranks high in abrasion, hardness, and toughness, although low in cementing value. Further evidence of the quality of the limestone is furnished by its long life in streets in Zanesville, and in strips of roads in the county. As previously stated, the average thickness of this limestone in Muskingum County is approximately 3 feet, which will yield about 11,000 tons of limestone per acre or enough to build about 3.7 miles of standard macadam road. Owing to the proximity of the limestone to many of the roads in the western half of the county and to the availability of the material along hillsides and along stream beds, good highways should be built at a low cost. The crushed stone is suitable also for concrete in the construction of culverts, bridges, retaining walls, etc. In the opinion of the writer the chief value of the Putnam Hill limestone in this county is for road construction and the material readily available is sufficient to supply all the needs in the townships in which the stone is present.

Next to road building the most important use of the Putnam Hill limestone in Muskingum County is for agricultural purposes. The soils in the western half of the county are derived largely from the Allegheny and Pottsville rocks and are relatively low in lime and magnesia, hence they are generally acid in character. Limestone is needed to neutralize this acidity as well as to furnish the legumes, especially, with the necessary calcium and magnesium oxides. The Putnam Hill limestone, either in the raw or the calcined state, is well suited for this purpose. The analysis previously given shows that the combined content of calcium and magnesium carbonates in the raw stone is 94.36 per cent which warrants its extensive use. Near Mt. Sterling this limestone is prepared by L. Dick for agricultural purposes. The limestone, 4 feet 7 inches in thickness, is quarried on the farm of W. P. Burley, and is then reduced to powder by a Jeffrey pulverizer. The machinery is moved from place to place, but a good supply of

the product is kept in a permanent storage house. The limestone is used locally and is pronounced by the farmers to be satisfactory. The impurities in the limestone are also sufficiently low so that the rock on calcination rapidly slakes to the hydrate which is readily soluble in water and thus capable of neutralizing quickly the soil acidity. On calcination the Putnam Hill limestone will yield a product with the following approximate composition:

Lime, CaO	90.40
Magnesia, MgO	1.70
Silica, SiO_2	3.93
Alumina, Al_2O_3	1.70
Ferric oxide, Fe_2O_3	1.92
Titanic oxide, TiO_2	.09
Phosphorus pentoxide, P_2O_5	.12
Sulphur, S	.14

The sum of the lime and magnesia is thus more than 92 per cent, which is only a few per cent less than the best agricultural limes on the market. The phosphorus pentoxide has a slight value, and the other components are not detrimental. The Putnam Hill limestone is not regularly calcined at any place in this county. Where coal is plentiful, small kilns are occasionally burned by the farmers for local use. A layer of logs is placed on the ground, then alternate layers of limestone and coal until the pile is 5 or 6 feet in height. This is then fired and allowed to burn which requires several days. The results are only fairly good, but the method requires no costly preparation. In fact it should be more largely practiced as both coal and limestone occur on many farms which may thus be improved at a low cost and with no great expenditure of labor. About 2 miles north of Zanesville, and east of the Muskingum River, this limestone was at one time regularly calcined in lime kilns for the general trade. The product was used principally for mortar and plaster. Owing to the content of iron oxide the color of the burned lime is slightly gray, which excludes it for the white coat in plastering. It forms a hot lime and is very satisfactory for most purposes. Its place, however, has been taken by the white limes of northern and western Ohio.

For fluxing in iron smelting the Putnam Hill limestone ranks not far below the limestone obtained from the quarries at Columbus and Kelleys Island. Its value is as follows:

To slag		*Fluxes*		*To iron*	
Silica, SiO_2	2.25	Lime, CaO	51.70	Iron, Fe	.77
Alumina, Al_2O_3	.97	Magnesia, MgO	.97	Phosphorus, P	.03
Titanic oxide, TiO_2	.05				
	3.27		52.67	Total produced	.80

To Slag—(Continued.)		*Fluxes—(Continued.)*		*To iron*
Lime, CaO, Magnesia, MgO	3.27	Lime, CaO, Magnesia, MgO	3.27	(See preceding page.)
Calcium sulphide, CaS, formed	.24	Lime, CaO to CaS	.28	
Total slag produced	6.78	Part used	3.55	
		Total available	49.12	

A comparison of these limestones follows:

	Slag produced	*Available fluxes*	*Iron produced*
Putnam Hill	6.78	49.12	.80
Columbus[1]	6.00	50.30	.38
Kelleys Island	4.32	51.48	.21

The Putnam Hill limestone was formerly used by the charcoal furnaces in the region, but has not been used to any extent by modern furnaces. The above figures show, however, that this county is not wanting in a limestone that may be used with success for fluxing. As previously stated, the Maxville limestone along Jonathan Creek is also suitable for this purpose. The Putnam Hill limestone is used in Muskingum County for many minor purposes, such as cellar walls, barn and silo foundations, walks, steps, curbings, retaining walls, etc. It is too high in iron oxide and alumina for use in the manufacture of the best grades of glassware.

SHALE OVERLYING THE PUTNAM HILL LIMESTONE

In large areas in the western and northern parts of Muskingum County shales make up the interval from the Putnam Hill limestone to the Ferriferous member or, as this bed is so often absent, to the Lower Kittanning clay. The usual measurements of the deposits are between 30 and 50 feet, but the extremes are considerably greater. The shale in the lower part of the interval is usually argillaceous and occasionally calcareous in composition, whereas that in the upper part is generally siliceous, in fact it frequently gradates into shaly sandstone. In many localities the Clarion sandstone replaces a part or all of these beds. Shales in this interval are present in some volume in all the townships except Harrison, west of the Muskingum River, and in Wayne, Washington, Madison, Adams, and Monroe east of this stream. The most prominent developments, however, are found in Newton, Springfield, Hopewell, Falls, Muskingum, and Cass townships. These beds will be traced very briefly, as so many sections showing the thickness and character of the rocks in this interval have been given.

At South Zanesville these shales are utilized for the manufacture

[1]Geol. Survey Ohio, 4th Ser., Bull. 20, pp. 344-45.

of both paving block and building brick. They are mined by stripping and open quarry methods. The measurements taken at the plant of the National Paving Brick Co. are given below:

		Ft.	In.
Clay, plastic	*Oak Hill*	9	--
Limestone, fossiliferous, *Hamden*		1	--
Clay, part flint		2	--
Coal smut, *Lower Kittanning*		--	1
Clay, plastic, good	*Lower Kittanning*	4	--
Clay, siliceous, with sandstone layers		4	--
Sandstone, shaly		5	--
Shales, gray, siliceous		38	--
Limestone, *Putnam Hill*		1	10

The shales in the 38-foot stratum overlying the Putnam Hill limestone, as well as the clays on the Lower Kittanning and on the Oak Hill horizons, are used in the manufacture of ware. The shaly sandstone which here averages about 5 feet in thickness is excluded. At Putnam Hill, Zanesville, these shales are not only well exposed, but have typical thickness and character. The section recorded follows:

	Ft.	In.
Coal blossom, *Middle Kittanning*	2	--
Clay, shale, and covered	42	--
Shale with thin sandstone layers	14	6
Shale, gray	43	--
Limestone, *Putnam Hill*	3	2

These shales extend northward with few wants, but with some contraction across Falls, Muskingum, and Cass townships. They are also of moderate thickness in eastern Licking and Jackson townships. In many places east of the Muskingum River shaly sandstones occupy the upper part of the interval or are interstratified with the shales. In northern Washington and southern Madison townships shales predominate in this part of the geological column, but in much of the remainder of these areas the shales are partially or completely replaced by the massive Clarion sandstone.

At present these shales are utilized at only one place in the county, and that is at South Zanesville by the National Paving Brick Co. Paving blocks are the chief product although building brick are also made. The deposits at this place are quite uniform in composition throughout the quarry. The shales are siliceous in character, bluish-gray in color, and rather free from concretions. On weathering or grinding they are readily reduced to plastic muds which have good working and drying qualities. The ware vitrifies at moderate temperatures to a tough, dense body of a dark-red color. It has a good rating in the markets.

CLARION SANDSTONE

The Clarion is one of the most conspicuous sandstone beds in Muskingum County and in the vicinity of Zanesville it has furnished

material for ordinary construction for many years. The position of the member is above the Putnam Hill limestone and below the Clarion coal. Owing to the fact, however, that not only this coal, but the Ferriferous limestone as well, are so local in extent, the upper surface of the sandstone more often lies just below the Lower Kittanning clay. In local areas also the Clarion sandstone replaces the underlying Putnam Hill limestone. In a general way, the member extends in a belt northward along the lower courses of Brush Creek in Brush Creek Township, thence along the Muskingum River in Wayne, Washington, and Madison townships to Wills Creek in the northwestern part of Adams Township. The member is locally present west of this belt, but is generally thin and shaly.

In Brush Creek Township the Clarion sandstone forms very prominent cliffs along Brush Creek where this stream has cut its way near the base of the hills. The bed is from 20 to 40 feet in thickness and lies just below the Lower Kittanning clay. The rock is usually somewhat loosely cemented and is often broken by shaly partings. In Wayne Township this sandstone seldom expands to more than 30 feet in thickness and in most of the area it is thin, shaly, or even wanting. The member is best developed in Washington Township where the rock is very thick and massive. Near Wortley, north of Zanesville, there are abandoned quarries from which considerable stone has been removed for local uses. The main ledge, which is unbroken by distinct partings, is from 20 to 30 feet in thickness and is underlain by other beds which are softer and more shaly in character. The prominence of the Clarion sandstone along the Muskingum River from Zanesville to Gilbert is well defined by the bold escarpment which in places terminates in cliffs from 30 to 60 feet in height. In the cut of the Baltimore & Ohio Railroad 3 miles north of Zanesville, the member is more than 40 feet in thickness and either replaces or lies on the Putnam Hill limestone. North of this on the property of John Mahoney the bed measures 75 feet in thickness and lies 30 feet below the Middle Kittanning coal. The general relation of the Clarion sandstone to other beds is shown in the following section taken on the C. E. Stotts property located one-fourth mile south of Gilbert:

	Ft.	In.
Clay, light, *Lower Kittanning*	4	--
Shale and covered	10	--
Sandstone, shaly } *Clarion*	5	--
Sandstone, massive } *Clarion*	41	--
Disconformity.		
Clay, light, siliceous	1	5
Limestone, *Putnam Hill*	4	1

The Clarion sandstone is very thick along the lower course of Blount Run east of Gilbert, but it thins or is wanting in the northern

part of Washington Township. Along the Muskingum River south of the mouth of Symmes Creek in Madison Township the member is generally wanting. It has massive thickness, however, along Symmes Creek and along North Fork in the vicinity of the crossroads and up these streams for a mile or two. The bed is from 20 to 60 feet in thickness and rather free from shaly partings. It forms bold escarpments along the Muskingum River in the northeastern part of Madison Township and along Wills Creek in the northwestern part of Adams Township. It is a massive bed, more than 60 feet thick in places, and resistant to weathering agencies.

Economic Value

The Clarion sandstone in Muskingum County is massively bedded and usually rather free from well-defined bedding planes or shaly partings. It is cross-bedded, but this is far more prominent on weathered surfaces than on fresh exposures. There is but little tendency, however, for the rock to split on weathering along these cross-bedding planes. The bonding materials, in the main, are clay and iron oxides with small quantities of other components. Owing largely to the oxidation of the iron compounds the stone hardens considerably on seasoning. The quartz grains are well-rounded and rather large. The most abundant accessory mineral is muscovite. Well under cover the stone is very uniform in color, but along the outcrop it is in places conspicuously banded. When green the material is soft and easily worked. Concerning this sandstone, Orton states:

> It has been used quite extensively for building canal locks, foundations, and for sidewalk pavements. Some of the oldest buildings in Zanesville are constructed entirely of this material, and it is found that the stone is more capable of resisting atmospheric agencies than of resisting the abrasive action to which it is subjected in sidewalks. This material is easily obtained in great abundance and of fair quality, and is the most important among the building stones found in the neighborhood of Zanesville. The most conspicuous use yet made of the stone is in the construction of the courthouse of Tuscarawas County. It has been found susceptible of ornamentation to a marked degree.[1]

The Clarion sandstone is now but little used even for minor purposes in Muskingum County.

CLARION OR NO. 4a COAL

Stratigraphy and Extent

The Clarion or No. 4a coal in Muskingum County has excellent thickness in a small area in the vicinity of Coaldale, in Hopewell Township, where it has been mined for many years, and is the main local fuel supply. In the remainder of the county, where the bed is due above drainage, scarcely a trace of it is seen, as its place is taken by

[1]Geol. Survey Ohio, Vol. V, p. 604.

thick beds of shale or sandstone, which occupy the interval from the Putnam Hill to the Ferriferous limestons and flint, or to the Lower Kittanning clay where this Ferriferous member is absent. On the average the Clarion coal lies about 28 feet above the base of the Putnam Hill limestone and just below the calcareous shales or argillaceous limestones, which appear to be directly related to the Ferriferous or Vanport member. The correlation of this coal in the Coaldale district of Muskingum County with the Clarion bed in the large field in southern Ohio is based on its position with reference to such well-established members as the Lower and Middle Kittanning coals, the Upper and Lower Mercer limestones, the Putnam Hill and Ferriferous limestones, and the Upper Mercer and Tionesta coals, which are less persistently developed, but which are followed with some certainty. There is a gradual thinning of the intervals, however, as the beds are traced northward. The position of the Clarion coal in Jackson County, where the bed is well developed, and of the bed considered Clarion in Muskingum County, with reference to other members, is shown in the following table, in which the intervals given are from the base of the Clarion to that of each member respectively:

	Jackson County	Muskingum County
Middle Kittanning coal	85	51
Lower Kittanning coal	43	25
Clarion coal	--	--
Brookville coal	20	28
Tionesta coal	45	51
Upper Mercer ore and limestone	73	73
Upper Mercer coal	98	83
Lower Mercer limestone	125	96

A comparison shows that the intervals from the Clarion coal to the Brookville coal, to the Tionesta coal, and to the Upper Mercer limestone or ore are about the same in the two counties, but those to the Upper Mercer coal and to the Lower Mercer limestone are greater in Jackson County. This difference is due largely to the increased thickening of the interval between the Lower Mercer and Upper Mercer limestones. In Jackson County this interval is 52 feet, whereas in Muskingum County it is only 23 feet. When this expansion is considered the position of the Clarion coal with respect to the Lower Mercer limestone is about the same in the two counties. The difference in the position of the Clarion coal with respect to the Lower Kittanning or to the Middle Kittanning coal in Jackson County and in Muskingum County is due largely to the general thinning or absence of the thick beds of shales and sandstones in the intervals, and to the patchy development of the Ferriferous member as the beds are traced northward from southern Ohio. Further, the Lower Kittanning coal is generally wanting, so that the Middle Kittanning clay and shale merge with those of the Lower Kittanning member. The general succession of

the beds is the same in both areas, and in the opinion of the writer the coal present near Coaldale, in Hopewell Township, is only a distant outlier of the main body of Clarion coal in southern Ohio. The content of pyrite in the parting between the two coal benches of the bed at Coaldale corresponds in a general way to the almost constantly high content in the parting between the lower and the middle benches of the Clarion coal in Vinton, Jackson, Scioto, and Lawrence counties. During this period in Muskingum County the prevailing conditions were more favorable for the deposition of shales and sandstones, which in so large a part of the area completely replace both the Clarion coal and its associated clay.

Hopewell Township.—The main deposit of Clarion coal in Muskingum County extends along the ridges from Coaldale to the George School in the southern part of Section 11. The total area is less than 3 square miles, but the bed has excellent volume and has been mined for many years, not only for the immediate neighborhood, but to supply the people along the National Road for many miles west of this locality.

Just north of Coaldale the Clarion coal was formerly mined on the farms of F. E. Dick and H. B. Dick. The bed is reported to be about 6 feet in thickness, but the main area is exhausted. The stratum was not observed on the north end of this ridge or on Flint Ridge north of Kent Run. Just north of the National Road, 1 mile west of Coaldale, the clay, with a thin blossom of Clarion coal, was exposed below beds of shaly limestone, and about 55 feet above the Upper Mercer black flint. South of Coaldale, at the mines of G. L. Porter, the following record was obtained:

		Ft.	In.
Coal blossom, *Middle Kittanning*		3	--
Clay, shale, and covered		26	--
Sandstone		5	2
Limestone, shaly, gray, fossiliferous	*Ferriferous*	11	--
Limestone, hard, gray, fossiliferous	*Ferriferous*	--	7
Shale, dark, calcareous		--	6
Coal, good	*Clarion*	--	5
Shale	*Clarion*	--	1
Coal, somewhat bony	*Clarion*	--	4
Coal, good	*Clarion*	3	8
Shale, pyritiferous	*Clarion*	--	5
Coal, good	*Clarion*	1	8
Coal, bony	*Clarion*	--	2

This record establishes the position of the Clarion with reference to the well-recognized Middle Kittanning coal. Further, it shows that the roof of the bed is the shaly limestone which is directly associated with the flint beds on Flint Ridge, as will be shown later. The thickness of the coal benches just shown is very constant in this area, but the measurements of the pyrite partings vary from 2 inches to 1 foot. The coal is regularly mined by drifting and is hauled from the mine by

mule power. A tipple is provided with screens for grading the fuel, and with bins from which the fuel is conveyed directly to the wagons. During the fall and winter 10 men are usually employed, but during the spring and summer only 3 or 4 men. A large part of the fuel consumed for many miles around is obtained from this mine and the quality is reported to be very good, especially for domestic purposes.

The Clarion coal was formerly mined rather extensively on the property of William Dick, located in the northern part of Section 3. The thickness and character of the bed are reported to be the same as at the mines of G. L. Porter. The coal is overlain by 9 feet of fossiliferous shales and limestones and lies 47 feet below the Middle Kittanning coal. At another opening on the same property the interval from the Clarion coal to the Bedford coal is 72 feet. At this place also the roof of the coal is composed of fossiliferous shales and limestones 8 feet or more in thickness. The Clarion coal is thin or wanting along the ridge in the western part of Section 10, but is present on the knobs in the northeastern part of this area, and is mined for local use on the farm of Ira Morrison. The record obtained follows:

		Ft.	In.
Limestone, fossiliferous, shaly	*Ferriferous*	2	--
Shales, fossiliferous		2	--
Coal, good	*Clarion*	4	--
Shale, pyritiferous		--	6
Coal, good		--	11
Coal, impure		--	7
Clay		1	--

The blossom of the Clarion coal was observed along the ridge in the southwestern part of Section 2, but no good measurements of the bed were obtained. In the central part of Section 11 on the land of Jesse George the coal measures as follows:

		Ft.	In.
Shale, dark		--	6
Coal, impure	*Clarion*	--	10
Shale		--	2
Coal, good		2	--
Coal, somewhat bony		--	4
Coal, good		1	9
Shale, pyritiferous		--	5
Coal		1	8
Coal, somewhat bony		--	4

In this mine the pyrite parting in some places is wanting, but in other places it varies in thickness from 1 inch to as much as 1 foot. The thickness of the coal benches is rather constant throughout the mine. At another opening near the George School on this property the coal has about the same measurement and structure, but it lies only 25 feet below the Middle Kittanning coal. The Clarion coal extends along the ridge in the northwestern part of this section, but

no mines were opened when the region was visited in 1916, hence no measurements were obtained. It lies about 82 feet above the Lower Mercer limestone, and is overlain by thick beds of fossiliferous shales and shaly limestones. In the southern part of Section 11, on the farm of C. E. Westcott, the record given below was obtained:

		Ft.	In.
Limestone, shaly, fossiliferous, *Ferriferous*		10	--
Coal, bony	*Clarion*	--	4
Shale		--	1
Coal		--	3
Shale		--	1
Coal		--	4
Shale		--	4
Coal		4	--
Shale, pyritiferous		--	5
Coal		2	--
Clay		2	--

In this mine the thick bench of coal varies from 3 feet 6 inches to 4 feet in thickness; whereas the lower bench is very constant. The upper coal is variable in the thickness of its partings and in the character of the fuel. The pyrite varies from 1 inch to 1 foot in thickness, but averages about 5 inches. The full thickness of the shaly limestones overlying the coal was not determined, but from appearances it exceeds the measurement given above. On the ridge east of the George School, in Section 12, the Clarion coal is thin and not persistent. In the northern part of Section 14 the bed was formerly mined on the property of J. C. Ardrey, where it has the following average structure and thickness:

		Ft.	In.
Limestone, shaly, *Ferriferous*		10	--
Coal, with shale partings	*Clarion*, reported thickness	1	--
Shale		--	4
Coal		4	--
Shale, pyritiferous, not generally present		--	2
Coal		2	--

The middle or thick coal bench is reported to vary from 2 feet 8 inches to 4 feet in thickness. At a new opening, west of the above, the coal thins rapidly and finally disappears, being replaced by the shaly limestone. South of this place the bed was not found, and in fact it was not observed elsewhere in Hopewell Township.

Springfield Township.—The Clarion coal was observed at only one place in Springfield Township, which was along the road in the northeastern part of Section 18. The outcrop conditions indicate that the bed is thin and of little value.

In the northern part of Muskingum County, especially in Cass Township, the Ferriferous limestone is well developed in local areas. No indication of the Clarion coal or even its clay was observed below the limestone.

Economic Value of Clarion Coal

The chief value of the Clarion coal in the Coaldale field of Muskingum County is for domestic fuel in this vicinity and westward along the National Road in Licking County. In this locality other coals are thin or impure or the deposits are very local; hence the Clarion bed is of value as it is in such volume that it may supply the local demand for many years. The average measurement of the bed is approximately 6 feet 6 inches. Of this usually more than 5 feet 6 inches is good marketable coal. The yield of fuel in such a bed, counting 60 per cent available in mining, is approximately 5,900 tons per acre. The roof of the coal everywhere in the Coaldale field is calcareous shale and shaly limestone, which under heavy cover are solid and firm, but which under shallow cover are considerably jointed and thus somewhat treacherous in mining. The floor of the coal is a siliceous clay well able to support the weight of the overburden where the mines are operated in a systematic way.

The Clarion coal in the mine of G. L. Porter, which is located just south of the village of Coaldale, Hopewell Township, was sampled by R. E. Lamborn in August, 1917. A sample 5 by 12 inches was cut in the coal near the head of the mine and thus well under heavy cover. The coal was bright and solid and the mine dry. Analyst Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Proximate		Ultimate	
Carbon	67.28	Moisture	6.89
Hydrogen	5.57	Volatile matter	41.49
Oxygen	14.24	Fixed carbon	42.92
Nitrogen	1.19	Ash	8.70
Sulphur	3.02		
Ash	8.70		

Calorific value { 6,706 calories. / 12,071 B. t. u.

Air drying loss of moisture, 2.3 per cent.

Fusion of ash { incipient 1,125° C. / complete 1,153° C.

The Clarion is an oily coal tending somewhat towards the coking type. It is only moderately free-burning, ranking in this respect, however, above the Clarion coal of southern Ohio. The coal is solid and firm; hence it mines in good-sized lumps with only a small loss in fine material. The ash is moderate in quantity and gray in color, and at the ordinary temperature produced in burning it does not clinker badly. The coal is well liked for domestic purposes, for which it is largely used. The pyritiferous shale associated with the Clarion coal contains 2.46 per cent sulphur.

FERRIFEROUS, VANPORT, OR GRAY LIMESTONE

Stratigraphy and Extent

In ascending order the important rock stratum above the Clarion coal is the Ferriferous or Vanport limestone, which is also often called Gray limestone owing to its color. This member is not persistent and is variable in character in the western part of Muskingum County where the bed is above cover. However, the scattered deposits of this member may be followed with some certainty from Perry County on the south into Coshocton County on the north. From Perry County it may be traced southward to the large and important field in Vinton, Jackson, Gallia, Scioto, and Lawrence counties, where it has characteristic development and excellent continuity. Owing to many wants in deposition and to rapid changes in character the bed is followed with more difficulty from Coshocton County northeastward to Mahoning and Columbiana counties where it again has good volume, and from where it has been directly traced into Lawrence and Beaver counties, Pennsylvania.

Two well-defined phases of the Ferriferous member are present in Muskingum County. In most of the county the upper phase is a bed of rather pure flint or limestone, in many places several feet in thickness. The flint is best represented by the massive stratum that extends along Flint Ridge from Poverty Run in Hopewell Township, Muskingum County, to the Porter School in Franklin Township, Licking County. Dr. Orton assigned this rock to the horizon of the Ferriferous limestone.[1]

Miss Clara Gould Mark also assigns the flint to this horizon. In 1916-17 the members of this Survey traced the stratum by stringers of flint and impure limestone to Bairds Furnace, Hocking County, where the member is a true limestone, definitely known to be correlative with the more massive and persistent Ferriferous beds of southern Ohio. Further, in its extension northward from Flint Ridge, Muskingum County, the stratum undergoes many changes, as it may be represented by thin local beds of flint, or by flint and limestone, or by limestone alone. Along the ridge known as the Highlands, in Cass Township, the horizon is marked locally by a thick bed of gray limestone very similar to that present in southern Ohio. North of this, along Graham Ridge, in Coshocton County, thin beds of flint again appear, and near Warsaw local deposits of impure limestone were observed. Similar conditions were noted in parts of Tuscarawas County. Although local, variable, and scattered, the deposits of this flinty phase in Muskingum County are sufficiently pronounced to be followed with certainty, and in the opinion of the writer they are correlative with the Ferriferous limestone of eastern and southern Ohio.

[1]Geol. Survey Ohio, Vol. V, p. 870.

The lower phase or the Ferriferous member is shaly sandstone, siliceous shale, calcareous shale, shaly limestone, flinty limestone, or calcareous flint, or some combination of these rocks. In a few localities both the lower and upper phases are present in the same section, but at other places only one type appears. The lower phase is especially conspicuous in the vicinity of Coaldale and on Flint Ridge in Hopewell Township, where the deposit is made up of beds of calcareous shale, shaly limestone, and calcareous flint. Likewise it is equally well developed and similar in character on the hills and ridges near Shannon in northwestern Muskingum Township, and near Symmes Ford in western Madison Township. If the rocks were all present in regular order the succession would be Clarion coal, secondary phase of the Ferriferous limestone which is represented by calcareous shale or flinty limestone, the primary phase of the same member which in this county is more often relatively pure flint than limestone. Owing to the patchy nature of the deposits in Muskingum County, however, this order is not attained, but the Clarion coal and shaly limestone have good thickness near Coaldale in Hopewell Township, and the shaly limestone and massive flint are well developed north of this on Flint Ridge. This lower or secondary phase of the Ferriferous member appears to be correlative with the calcareous and carbonaceous shales, similarly placed with respect to the Clarion coal and Ferriferous limestone proper in the southern Ohio field. Both phases were laid down during the same general deposition period, but under slightly different conditions. In the opinion of the writer the separation of these two phases into different members is not warranted, for there is no general change in the type of sediments, and there is no definite break in the stratification. The light-colored flint or gray limestone of the upper phase in many places is bedded directly on the impure flint or shaly limestone of the lower phase.

In Muskingum County the average interval from the base of the Putnam Hill limestone to the base of the lower phase of the Ferriferous member is about 35 feet, and to the base of the upper phase it is approximately 41 feet. The top of the flint or limestone lies about 10 feet below the Lower Kittanning coal and about 41 feet below the Middle Kittanning coal. These intervals, however, vary considerably, owing largely to wants and poor development of the coals and clays, and to local thickening of the interbedded shales and sandstones. Further, the thickness of both phases of the Ferriferous member is subject to rapid changes. The thickness of the upper phase varies from a few inches to as much as 10 feet, and that of the lower phase varies through wider limits, the minimum being only a few inches, but the maximum being as much as 25 feet.

In the flint and limestone of the upper phase *Fusulina* are especially abundant and are delicately preserved. Brachiopods, pelecypods,

and gastropods are also present, being more conspicuous, however, in the limestone than in the flint. The impure limestones and calcareous shales of the lower phase in many localities are rich in fossil remains of the above types and afford excellent collecting. The best localities will be noted as the rocks are taken up in more detail.

The Ferriferous member is due above drainage in all the townships west of the Muskingum River and in Wayne, Washington, Madison, Adams, and Monroe east of this stream.

Hocking County.—In the vicinity of Gore and Bairds furnaces, in northeastern Hocking County, the Ferriferous member is very steady, and it may be traced with but few wants from this locality southward to the extensive field in southern Ohio. These furnaces obtained not only their main supply of ore for smelting, but also their supply of limestone for fluxing from this horizon. In this region the Ferriferous limestone, from 1 to 4 feet in thickness, is locally represented by gray limestone or by light-colored flint, or by both. In general appearance the flint is very similar to that on Flint Ridge in Muskingum County.

Perry County.—Local patches of flint or limestone were observed on the Ferriferous horizon in so many places in Perry County that the member may be easily followed. The bed is more often flint than limestone and is seldom underlain by the shaly limestone representing the lower phase observed in Muskingum County. In order to show the general stratigraphy of the beds a few sections are given below. The following record was taken along the road in Section 14, Monday Creek Township:

	Ft.	In.
Clay, plastic, with ore nodules, *Oak Hill*	5	--
Sandstone, shaly	7	--
Coal blossom, *Lower Kittanning*	1	6
Clay, light, plastic, part siliceous	16	6
Ore, *Ferriferous*	--	10
Limestone, gray, fossiliferous, *Ferriferous*	1	6

In this vicinity the limestone is from 1 to 3 feet in thickness and in places it is flinty in character. The interval from the limestone to the Lower Kittanning coal is about the same as it is in Muskingum County. North of this the horizon is more often marked by flint or chert.

Similar deposits were noted on the ridges south of New Lexington. Along the road in the northern part of Section 11, Clayton Township, the following rocks were exposed:

	Ft.	In.
Coal blossom, *Lower Kittanning*	1	--
Clay and covered	5	--
Flint, light, nodular, fossiliferous, *Ferriferous*	1	--

At this place the Ferriferous flint lies exceptionally close to the Lower Kittanning coal. The interval from the flint to the Upper

Mercer limestone is 75 feet, which is about normal. The intervals from the Ferriferous flint to other well-known beds in the northern part of Section 4, Harrison Township, are shown in the record given below:

	Ft.	In.
Coal blossom, *Middle Kittanning*	4	--
Clay and covered	20	--
Limestone, siliceous, very fossiliferous, *Ferriferous*	1	6
Shale, gray	27	8
Limestone, *Putnam Hill*	1	--

Large *Aviculopectens* were especially conspicuous in the Ferriferous limestone at this place. The Lower Kittanning coal is absent in this locality and its clay so merged with that of the Middle Kittanning coal that the two were not differentiated.

Newton Township, Muskingum County.—In Newton Township, nodular iron ore, shaly limestone, and fossiliferous shale are locally present to mark the horizon of the Ferriferous limestone. In Section 20, about 1 foot of light fossiliferous flint was observed, and in sections 21 and 28 thin beds of shaly limestone are locally present.

Brush Creek and Harrison Townships.—A few thin deposits of nodular flint, representing the Ferriferous member and lying about 20 feet below the Lower Kittanning coal, are present along Brush Creek in Brush Creek Township. No limestone was observed. In Harrison Township the horizon is above drainage along the Muskingum River to Philo, but owing to the depth of covering along the valley the rocks are poorly exposed.

Springfield Township.—Isolated patches of Ferriferous limestone were noted in the western part of Springfield Township, and beds of iron ore and fossiliferous shales are present on the horizon in places in the eastern part.

Hopewell Township.—Both phases of the Ferriferous member are better represented in Hopewell Township than in any other part of the county. The massive bed of light-colored flint worked extensively by the aborigines for their crude implements belongs to the upper phase and extends from Poverty Run westward along Flint Ridge, and its spurs to the Porter School in Franklin Township, Licking County. The lower phase of calcareous shales and impure limestones is not only present along Flint Ridge, but also along the ridges in the vicinity of Gratiot, Coaldale, and Mt. Sterling. In the central part of Section 13, south, the following rocks were exposed for measurement:

	Ft.	In.
Coal blossom, *Middle Kittanning*	2	--
Clay, shale, and covered	18	--
Shale and covered	14	--
Limestone, shaly, thin-bedded, *Ferriferous*	8	--

	Ft.	In.
Covered	3	--
Sandstone, massive	15	--
Covered	53	--
Flint, light, ferruginous, *Upper Mercer*	--	10

The shaly limestone in the above section is the lower phase of the Ferriferous member, and is fossiliferous and in places flinty. North of this these beds form the roof of the Clarion coal which has excellent thickness.

This shaly limestone of the Ferriferous member extends over the whole of Section 11, and is from 5 to 20 feet in thickness. It is everywhere fossiliferous, the fossils being the most abundant, however, in the more shaly parts and in the calcareous shales interbedded with the limestone layers. The character of the member is much the same in Section 10, south. In the southern part of Section 2, the following measurements were obtained:

		Ft.	In.
Clay, clay-bond sandstone and covered		16	--
Limestone, dark-gray, shaly, very fossiliferous	*Ferriferous*	3	6
Limestone, hard, fossiliferous		--	6
Coal blossom, *Clarion*		2	--

East of this the Ferriferous limestone thins rapidly and soon becomes wanting, but to the west it has excellent thickness. South of Coaldale the thickness of the member is somewhat variable owing to the fact that the overlying sandstone often replaces a part of the upper layers. There is a well-defined disconformity at the base of the sandstone. South of this, in Section 3, south, the condition of the beds is much the same, but the shaly limestone in places expands to as much as 15 feet. About 1 mile east of Gratiot this limestone, 10 feet thick, was mined for road purposes. The rock at this place is thin to massive bedded, somewhat shaly, and dark-gray in color. It also contains many nodules of flint and is not especially fossiliferous. On the side of the hill just east of the quarry the total thickness of the beds exposed is 17 feet. The member extends southward along the ridge to Section 8, south, where it then passes above the summits of the highest knobs. Just north of Mt. Sterling, the Ferriferous is poorly developed, but near the Wise School the lower phase is again well represented.

Near the Wise School both phases of the Ferriferous member are present in good development and their contact is well exposed. Both the flint and limestone are very fossiliferous. The light flint near this school is correlative with the massive bed of this rock so prominently developed along Flint Ridge proper; whereas the shaly limestone is only a continuation of that described in the vicinity of Gratiot and Coaldale. The light flint is bedded directly upon the shaly limestone and thus appears to be only a phase of the same gen-

eral deposit. Both beds are also well developed on the ridge northeast of the Wise School, where the hillsides are thickly strewn with flint and impure limestone. At the forks of the road in the eastern part of Section 15, north, on the property of Harrison Drumm, the following rocks were exposed for measurement:

		Ft.	In.
Flint, light		2	--
Covered		1	--
Limestone, siliceous	*Ferriferous*	--	10
Covered	*Ferriferous*	1	--
Limestone, siliceous, thin to medium bedded	*Ferriferous*	15	--
Covered		6	--
Shale		19	--
Limestone, bluish-gray, fossiliferous, *Putnam Hill*		1	2

The flint of the Ferriferous member is light-colored, sparingly fossiliferous, and very pure. The bed may be traced almost continuously westward from this locality along Flint Ridge to the Porter School in Franklin Township, Licking County, and northward to the high knobs on the ridge south of Claypool School in southwestern Licking Township, Muskingum County. The secondary phase extends over much the same area. The limestone is thin to medium bedded, often shaly, and far more fossiliferous than the flint. The color is dark to bluish-gray, varying where weathered to buff shades. The strata are decidedly siliceous and some layers are flinty in character.

The shaly limestone of the Ferriferous member, which is the roof of the Clarion coal in the Coaldale field, lies in direct contact with the shale above the Putnam Hill limestone, and without any indications of a disconformity. It thus appears that there was no break in the deposition of sediments, but that in the Coaldale areas a shallow water condition prevailed so that the clay and coal were laid down. In Section 15, at the forks of the road west of this, 3 feet of light flint underlain by 19 feet of calcareous shale and shaly limestone were fully exposed. In Section 6 the light flint is about 5 feet in thickness and the shaly limestone nearly 20 feet. Along the main ridge in sections 4 and 7, north, the shaly limestone becomes flinty and maintains good thickness. The light flint measures from 2 to 6 feet and is very persistent. In Hopewell Township, east of Poverty Run, the lower or shaly limestone phase of the Ferriferous member is present in local areas, but the upper or light flint phase was nowhere observed.

This bed of shaly limestone is a continuation of that described west of Poverty Run, and is similar in texture. The limestone is very fossiliferous and affords excellent collecting. East of this, along the road near the residence of J. Brown, 14 feet of these shaly limestones was exposed, but the full thickness of the bed was not obtained. The

limestone extends along the ridges south and east to Section 11, where it passes into siliceous shales, or is replaced locally by a massive sandstone.

Licking County.—The flint beds of the Ferriferous member in Hopewell and Franklin townships of Licking County are the largest in Ohio, and were extensively worked by the aborigines, who dug hundreds of pits along Flint Ridge in the mining of this material. The stratum was evidently worked for a long period, and the material, identified by its characteristic fossils, is widely distributed. Much of the flint chipped into arrows, knives, scrapers, etc., and found in the burial mounds and earthworks of the mound builders, as well as that similarly worked and found on the surface in this and adjoining states, is from Flint Ridge. The field is of exceptional interest both to the geologist and archaeologist. The outcrop measurements indicate that the light-colored bed of flint is from 1 to 10 feet in thickness, and that it averages about 5 or 6 feet. This stratum is directly bedded on the shaly limestone, the thickness of which, from surface indications, is from 5 to 20 feet, or even more. Owing to the slumping of the flint and to the nature of the covering no good sections of the entire interval were obtained.

Along the ridge at the head of Berry Run, in Hopewell Township, the light flint is massive, and varies from 3 to 10 feet in thickness. The bed was mined by the aborigines more extensively in this locality than on either the western or eastern part of the ridge. A section taken in a ravine east of the crossroads follows:

		Ft.	In.
Flint, light	*Ferriferous*	5	--
Limestone, thin to medium bedded, shaly	*Ferriferous*	7	--
Covered		32	--
Sandstone, parts covered		32	--
Shale		1	--
Sandsto e		23	--
Shale, calcareous, with shaly limestone	*Lower Mercer*	1	--
Limestone, dark, siliceous	*Lower Mercer*	--	8
Shales, calcareous, with shaly limestone	*Lower Mercer*	5	--
Limestone, hard	*Lower Mercer*	3	6
Shale	*Lower Mercer*	--	2
Limestone, hard	*Lower Mercer*	1	8

In this locality the light-colored flint or upper phase of the Ferriferous member is bedded on the shaly limestone or lower phase. No separation, except an irregular bedding plane, is evident, thus suggesting that both rocks were laid down during the same general deposition period. In the above section the interval between the Ferriferous member and the Lower Mercer limestone is about normal for the region.

Springfield Township.—In Springfield Township, Muskingum County, the Ferriferous member lacks the characteristic development that it has in Hopewell Township, but the lower phase is represented

in a part of the area by a thick bed of shales with thin to medium-bedded layers of shaly sandstone. A section taken at Putnam Hill near Zanesville is approximately representative of the area:

	Ft.	In.
Coal blossom, *Middle Kittanning*	2	--
Clay shale and covered	42	--
Shale with thin to medium-bedded sandstones, lower phase of *Ferriferous* member	14	6
Shale, gray	43	--
Limestone, *Putnam Hill*	3	1

There is no evidence of the Clarion coal or of the light-colored flint. The sandstone layers in the shale, which are 14 feet 6 inches in thickness, become calcareous as they extend westward, and finally pass into the shaly limestone. Some of the upper sandstone layers locally take on a calcareous phase and are sparingly fossiliferous.

Falls Township.—The lower phase of the Ferriferous member in Falls Township is locally represented by a stratum of shale with thin sandstone layers interstratified. In the northwestern part of the area the upper phase, in a few places, is a true limestone, in which *Fusulina* are abundant. A section taken on the M. A. Russel farm, near the mouth of Big Run, follows:

	Ft.	In.
Limestone, light, fossiliferous, *Ferriferous*	--	8
Shale and covered	39	4
Limestone, *Putnam Hill*	1	--
Shale and covered	14	--
Flint, black, *Upper Mercer*	--	6

Muskingum Township.—Both limestone and flint appear on the Ferriferous horizon in Muskingum Township, but the beds are usually thin and the deposits widely scattered. In a few localities the horizon is marked only by nodular iron ore, bedded in shale. The record given below was measured along the road south of Section 14:

		Ft.	In.
Clay shale		5	--
Ore, nodular	*Ferriferous*	--	3
Limestone, dark-gray	*Ferriferous*	--	11
Shale		21	--

At this place *Fusulina* are abundant in the limestone. Along the road to the southwest of this the bed is represented by light to dark-colored flint, the thickness of which is about 1 foot.

An excellent section showing the relative positions of all the limestones from the Middle Kittanning coal to the Lower Mercer limestone was obtained along the road north of the Sandy Ridge School in the northeastern part of the township. The record follows:

	Ft.	In.
Coal blossom, *Middle Kittanning*	3	--
Clay and covered	3	--

		Ft.	In.
Sandstone, shaly		12	--
Shale and covered		7	--
Ore, nodular		--	2
Limestone, fossiliferous, *Hamden*		--	10
Clay, light, parts covered, *Lower Kittanning*		16	--
Covered		6	--
Flint, nodular, light, *Ferriferous*		1	--
Covered		2	--
Sandstone, shaly		31	--
Shales, part siliceous		22	--
Limestone, *Putnam Hill*		5	--
Clay, dark		1	--
Clay, light		2	--
Shale and covered		19	10
Flint, black		1	1
Limestone, flinty, *Upper Mercer*		1	--
Shale, dark		--	2
Coal, bony	*Bedford*	--	2
Shale		--	2
Coal		--	7
Clay, dark		--	8
Coal		1	4
Clay		2	--
Shale		7	--
Limestone, shaly	*Lower Mercer*	1	--
Shale		--	2
Limestone, hard		1	10
Shale		--	1
Limestone, hard		1	9

Licking Township.—The Ferriferous member is present on only a few of the highest ridges and knobs in the northeastern and in the southern parts of Licking Township. In these areas, however, the deposits have good thickness and characteristic development. In the southern part of the township the deposits are only an extension from the heavy deposits on Flint Ridge to which they are similar in every respect. Those in the northern part, however, are somewhat different, as the upper phase varies more towards limestone than flint. The following section was taken on the high knob, about 1 mile northeast of the village of Cottage Hill:

		Ft.	In.
Flint, light, scattered blocks	*Ferriferous*	3	--
Limestone, flinty, thin to medium-bedded		12	--
Shale and covered		4	--
Limestone, gray, *Putnam Hill*		6	--

The flint in the limestone beds varies in color from a light-gray to nearly black and contains many fossils. In places these thin to medium-bedded layers are nearly pure flint and indicate a uniform condition during the whole period of deposition. The interval in this locality from the Ferriferous member to the Putnam Hill limestone

North of the Licking River in Licking Township, the Ferriferous member is wanting except on the high ridges in the northeastern corner. On the S. H. Frazier farm located about 1 mile southwest of Shannon, thick deposits of flint are present near the summit of the hill. No good measurements of the beds were obtained, but the general appearance of the rock is the same as that below the light-colored flint along the northern extension of Flint Ridge east of Cottage Hill. In fact, it appears to be only a continuation of those deposits. The flint beds on the Frazier farm were also worked by the aborigines and many pits may yet be observed. The thickness of the member appears to be between 5 and 10 feet. The upper stratum, in places at least, is a gray nodular limestone about 1 foot in thickness. Both the flint and limestone are very fossiliferous, *Fusulina* being especially abundant. These deposits lie about 85 feet above the Lower Mercer limestone, and extend northward along this ridge into Jackson and Cass townships.

Jackson Township.—In Jackson Township only the highest hills and knobs in the extreme southeastern and northeastern parts are of sufficient height to contain the Ferriferous member. In the southeastern part the deposits are made up of limestone or flint or both and are very fossiliferous.

Cass Township.—The Ferriferous member in Cass Township is best defined in the southern part along the ridge known as The Highlands and along its spurs extending southward. The deposits vary from impure flint to shaly limestone and to solid limestone; and in thickness from 1 foot or less to as much as 10 feet or more. The material everywhere contains fossils, which are the most conspicuous and abundant, however, in the shaly limestone. Along the road one-half mile north of Shannon the following rocks were exposed for measurement:

		Ft.	In.
Limestone, gray Flint, calcareous	*Ferriferous*	1 2	8 --
Covered		1	10
Shales, gray		18	8
Limestone, *Putnam Hill*		1	2

At this place the 1 foot 8 inches of gray limestone is directly and irregularly bedded on the impure flint layers and contains some flint masses. The calcareous flint is thin to medium-bedded and gray to nearly black in color. It is similar in every respect to that of the lower phase of the Ferriferous member on the extension of Flint Ridge, in northern Hopewell and southern Licking townships, and is evidently a correlative deposit. Both flint and limestone are very fossiliferous, *Fusulina* being the most abundant. These deposits are an extension of those described in the northeastern part of Licking Township. Near the Dutch School on The Highlands, the Ferriferous is a thick bed of

gray, fossiliferous limestone containing but little if any flint. In appearance it closely resembles the Ferriferous of southern Ohio. It is underlain by a clay which may belong to the Clarion coal, but no evidence of coal was observed.

The Highlands afford an opportunity for the study of the limestones in the upper part of the Pottsville and the lower part of the Allegheny formations, as all the members are present in fair and many in characteristic development. Along the ridge 1 mile west of Dresden, the Ferriferous member thickens and changes from an impure flint to a flinty or rather pure limestone. West of this along the ridge the stratum where observed varies from a flinty limestone to calcareous flint and from 1 to 3 feet in thickness. Both flint and limestone are fossiliferous. The member was not observed on Irish Ridge in the northern part of Cass Township.

Wayne Township.—In Wayne Township the Ferriferous member is poorly defined, as only isolated patches of nodular flint or of siliceous ores are present to mark its horizon. In a part of the area the place of the bed is taken by a massive sandstone.

Washington Township.—But little needs be said in regard to the Ferriferous limestone in Washington Township. From Zanesville to Gilbert it is replaced by the Clarion sandstone, and north of this it is seldom more than a thin bed of nodular flint or shaly limestone.

Madison Township.—Just east of Symmes Ford in Madison Township, shaly limestone or the secondary phase of the Ferriferous member is present in good thickness, and along Symmes Creek a few thin deposits of light-colored flint were observed. In the northern part of the area the member is largely replaced by the Clarion sandstone. The section taken along the ravine and road just east of Symmes Ford follows:

	Ft.	In.
Coal blossom, *Middle Kittanning*	3	--
Covered	45	--
Sandstone, shaly, part covered	15	--
Limestone, gray, shaly, part flinty, *Ferriferous*	9	6
Shale, dark, siliceous	12	6
Covered	9	--
Limestone, *Putnam Hill*	4	3

The Ferriferous limestone near Symmes Ford is similar in general appearance to that described in southwestern Cass, in northeastern and southern Licking, and in Hopewell townships. It is dark-gray, siliceous, and even flinty, and thin to medium-bedded. The rock is rather fossiliferous and affords fair collecting, as the fossils are well preserved and easily obtained from weathered material. No light-colored flint was observed in this locality.

Adams and Monroe Townships.—Only a few thin stringers of nodular flint or even shaly limestone representing the Ferriferous member were noted in either Adams or Monroe townships. These deposits are from 30 to 50 feet below the Middle Kittanning coal which is the main bench for reference. The impure limestone is very fossiliferous and somewhat blocky in structure.

Coshocton County.—The Ferriferous member extends northward from Muskingum County into Coshocton where it is represented by scattered deposits of impure limestone and flint. Two sections taken in this county will be given in order to show the general character of the bed and its relation to other well-known members. At Graham Corners, in the western part of Washington Township, the following rocks were exposed for measurement:

	Ft.	In.
Coal blossom, *Lower Kittanning*	1	--
Clay and covered	12	--
Shale and covered	9	--
Limestone, hard, siliceous, *Ferriferous*	3	--
Clay, light	5	--
Covered	33	--
Limestone, *Putnam Hill*	5	--

In this locality the Ferriferous limestone is thin to medium-bedded and light-gray to dark-gray in color. The lower layers are very fossiliferous. About one-half mile north of Graham Corners the bed is again exposed along the ridge road. The record follows:

		Ft.	In.
Flint, light-gray	*Ferriferous*	1	2
Limestone, flinty, shaly		2	--
Clay and covered		20	--
Limestone, *Putnam Hill*		3	--

The light flint of the Ferriferous member shown in the above section is strikingly similar in appearance to that so prominently developed on Flint Ridge and is evidently correlative. Further, the shaly limestone agrees in many respects with the lower phase of the Ferriferous deposits in Muskingum County. Similar beds were also noted north of West Bedford and in Section 3 of Bedford Township.

In a review of all the sections given in Perry, Muskingum, and Coshocton counties, the following general relations and conclusions are established. Deposits of flint or limestone, or both, occur along a definite horizon across the entire area. These deposits lie, on the average, about 18 feet below the Hamden limestone, which lies just above the Lower Kittanning coal, or above its clay when the coal is absent. These flint and limestone deposits in a part of the field are underlain by a bed of coal. This arrangement of strata corresponds to that of the Ferriferous limestone and Clarion coal of southern Ohio, in which field either one or the other may also be wanting in local areas.

Economic Value of the Ferriferous Limestone and Flint

The great value to the aborigines of the flint beds of the Ferriferous member in Muskingum County, and also in Licking County, is attested by the large quantities of earth and rocks mined in the excavation of the hundreds of pits scattered along Flint Ridge and along its spurs. This flint was certainly held in high esteem by these ancient people, who used it in the manufacture of implements for domestic purposes, for hunting, and for war. Arrows, knives, skinners, scrapers, hoes, and drills made of flint from this locality, and recognized by the remains, are scattered over a wide area in the Ohio Valley and in the Lake Erie region. Their method of quarrying the flint and of shaping the implements is a subject of interest, but it belongs more to the province of archaeology than to that of present-day geology and hence needs no further discussion here.

So far these deposits of Ferriferous limestone or flint have contributed but little to the welfare or wants of the people now living in Muskingum County, although the materials have a value for several purposes. The shaly limestone or lower phase of this member has been quarried in the vicinity of Gratiot for road metal and concrete stone used in the construction of the National Road. This limestone, although somewhat shaly, is considered very satisfactory for macadamizing. The main body of the stone has fair toughness and hardness, and the fine material has a cementing or bonding value. The parts of the old National Road constructed of this limestone alone are stated to have lasted for many years. For concrete work the crushed stone is screened to remove the argillaceous and shaly material which impairs the strength of the body. This stone was used to a considerable extent in the construction of the present concrete facing of the National Road between Mt. Sterling and Gratiot. Large quantities of this impure limestone are available for road or other purposes in the western part of Hopewell Township as well as in more local areas in Licking and in Cass townships. The deposits have excellent volume and are easily available without stripping, as they usually lie near the summits of the ridges and knobs. Owing to the thin to medium-bedded character of the layers the material is easily quarried and prepared for the crusher.

The light-colored flint or upper phase of the Ferriferous member, so well developed along Flint Ridge, is also available for road building. On account of its excessive hardness the solid flint from the deposits under cover would be difficult to quarry and also to reduce to the fineness desired. However, large quantities of this material, which is more or less shattered by interlacing cracks, due to expansion changes, and which on this account may be crushed with comparative ease, are strewn along the hillsides and in the ravines over a wide area and in proximity to many of the thoroughfares. The durability of the flint

is beyond question. Owing to the sharpness and angularity of the fragments, and to the low cementing value of the fine material, the flint is best suited for the main body or foundation of the road. The shaly limestone found directly below the flint bed is much better fitted for the top or surface coating. This flint may be used satisfactorily not only for the road foundation, but for the stone in all the concrete work required.

The chemical as well as the physical properties of the light-colored flint on Flint Ridge are such that the material may be utilized for the manufacture of silica brick or for potter's flint of white ware bodies. The deposit along the main ridge for a distance of more than 5 miles was sampled by taking pieces thrown out of the pits excavated by the aborigines. This sample weighing more than 100 pounds was properly crushed and prepared for analysis. The chemical work was done by Prof. D. J. Demorest, who reports the following results:

Silica, SiO_2	96.40
Alumina, Al_2O_3	1.52
Ferric oxide, Fe_2O_3	.48
Lime, CaO	.30
Magnesia, MgO	.04
Water, comb., H_2O	1.20
	99.94

In composition this flint compares favorably with the ganisters from Pennsylvania or with the quartzites of Wisconsin, both of which are now used largely in the manufacture of silica brick. Following are the analyses of these rocks:

	No. 1	No. 2
Silica, SiO_2	98.80	99.07
Alumina, Al_2O_3	.59	.52
Ferric oxide, Fe_2O_3	.21	.17
Lime, CaO	trace	none
Magnesia, MgO	.09	none
Water, H_2O	------	.06
Total	99.69	99.82

No. 1. Ganister, Bedford County, Pennsylvania.
No. 2. Quartzite, Rib Hill, Wisconsin, Wisconsin Geol. and Nat. Hist. Survey Bull. XVI, p. 45.

The above comparison shows that the flint of the Ferriferous member from Flint Ridge is on a par or nearly so with the best acid refractory materials of the United States. Its utilization for this purpose is more a problem of manufacture than a question of quality. The raw flint is hard to reduce by grinding to the desired fineness, but if it is given a preliminary heating with sudden cooling the material

so shatters that it is reduced with comparative ease. Owing to the angularity and incoherency of the particles the material is difficult to bond, so that the ware will withstand factory handling in the green state or shipping in the burned state. Two per cent of lime has but little effect in producing the strength of body desired. The use of other bonding agents, however, may be more effective. With the exception of the grinding and bonding, the general process of manufacturing this flint into ware is the same as that used for the ganisters and quartzites. The material is ground by jaw or spindle crushers, bonded with basic fluxes, molded by hand or by machinery, dried on pallets, and burned at high temperatures.

According to American and English investigators, the object desired in the manufacture of silica brick is to convert the material into tridymite, which is less subject to cracking or spawling than either quartz or cristobalite. Further, they show that quartz even in the presence of a flux passes with difficulty to tridymite; whereas amorphous silica as flint and chalcedony is readily converted to this form, and is therefore superior for this purpose to the crystalline varieties. The linear and volume changes of the flint when calcined at high temperatures are about normal for tridymite. The dense amorphous character of the material prevents rapid solution by unsaturated slags or premature disintegration by corrosive gases.

The quantity of the light-colored flint is large as the total area of the deposit is between 5 and 6 square miles, and as the average thickness of the bed is between 4 and 5 feet. In large areas the covering is shallow and may be removed by stripping at low cost. The specific gravity of the flint is about 2.59. Where the deposit is 5 feet in thickness the yield per acre would be about 17,600 tons of 2,000 pounds each. Counting 4 tons of material to 1,000 brick, this quantity is sufficient to make 4,400,000 brick. The utilization of the light-colored flint of the Ferriferous member in Muskingum County for the manufacture of silica brick is well worthy of careful consideration and investigation, especially as good brick material of the acid type is scarce in Ohio, and as the demand for such products becomes greater each year.

Flint was one of the original components used by the early potters in the manufacture of white ware bodies. It was calcined and then ground to the fineness desired. Later quartz sand, reduced to a fine powder, became the potter's flint of commerce and at present it constitutes the entire supply in the United States. The physical properties of flint or amorphous silica in both bodies and glazes are very different from those of quartz or crystalline silica, and in some respects the amorphous varieties are much superior to the crystallized. The quantity of very pure flint available for such purposes in Muskingum County is large, but the cost of preparing the material will far exceed that

of preparing the quartz sand; hence its use is prohibitive except for special purposes in high-grade ware. Possible minor uses of this flint in ceramic work are for balls of ball mills and for crushed flint for lining saggers. This flint if properly ground and bonded with clay should also make a good lining for acid Bessemer converters and for acid open-hearth steel furnaces as well as for the ladles used in these processes. When bonded with clay the flint forms a dense, strong body, very resistant to acid slags and capable of withstanding the high temperature employed.

Small quantities of flint from Flint Ridge have been utilized for building purposes. It is used mainly in porch columns, mantels, and ornamental figures in walls. Owing to the weather-resistant character of the material, and to the variety of colors available, this flint is suitable for decorative purposes and would be more largely utilized if the deposits were nearer to the lines of transportation. Attractive concrete is also made by using this flint. The concrete is composed of sand and cement and the variously colored flint, properly broken and sized. After the work is partially set it is brushed to remove the fine material which thus leaves the fragments of flint stand out in relief. The concrete is then allowed to stand until the mass is hard, when the exposed flint is cleaned with acid and washed thoroughly with water. Such walls are not only pleasing to the eye, but are resistant to weathering agencies.

This flint when crushed and graded would make an excellent material for the abrasive coating of sand paper. The hardness of the material and the angularity of the fragments give a high degree of cutting power, equal to or above that obtained from quartzite, which is now so largely used for this purpose. This flint finely comminuted may also be used in scouring powders employed for cutting stone or metal surfaces. Further, it would make an excellent sand-blasting material, but the cost of production is prohibitive owing to the cheapness of natural sands. There are many other uses for this flint in small quantities.

Along what is known as the Highlands in southern Cass Township the Ferriferous member, as previously stated, is a limestone of good thickness and purity. A sample of the material was taken near the Dutch School, and the results reported by Prof. D. J. Demorest are given below:

Silica, SiO_2	1.59
Alumina, Al_2O_3	.55
Ferric oxide, Fe_2O_3	1.05
Titanic oxide, TiO_2	trace
Lime, CaO	53.90
Magnesia, MgO	.54
Phosphorus, P	.059
Sulphur, S	.25

The approximate mineral composition of such a limestone is as follows:

Clay, $Al_2O_3.2SiO_2.2H_2O$	1.39
Quartz, SiO_2	.94
Pyrite, FeS_2	.47
Limonite, $2Fe_2O_3.3H_2O$	.86
Titanic oxide, TiO_2	trace
Calcium phosphate, $3CaO.P_2O_5$	.31
Calcium carbonate, $CaO.CO_2$	95.95
Magnesium carbonate, $MgO.CO_2$	1.13
Total	101.05

Such a limestone will give the farmers in this locality an excellent material for agricultural purposes. It will calcine readily, and the product on exposure to the atmosphere will slake to a fine powder. If properly ground the raw limestone should also give good results as it is sufficiently pure to be dissolved readily by the soil acids. It is also recommended for road metal or concrete stone. As the rock is very solid, and but little given to shelling or weathering, it may also be employed for minor building purposes, such as retaining walls, foundations, culverts, etc.

FERRIFEROUS OR BAIRD ORE

The Ferriferous ore, which has good thickness and continuity in the vicinity of Gore and Baird furnaces in Hocking County, where it was formerly extensively mined for charcoal iron, is poorly defined as it extends northward into Muskingum County. The ore is due in all the townships west of the Muskingum River, and in Wayne, Washington, Madison, Adams, and Monroe townships east of this stream. However, only a few scattered patches of Ferriferous ore from 1 to 5 inches in thickness were observed in the entire area. The normal position of the member is directly above the Ferriferous limestone or flint. The ore on the outcrop belongs to the limonite class and is somewhat siliceous in character. It has no value as the quantity is negligible.

LOWER KITTANNING OR NO. 5 COAL AND CLAY

Stratigraphy and Extent

The Lower Kittanning coal with its underlying clay lies about 10 feet above the Ferriferous member. This interval, however, is variable, owing to the poor development of both clay and coal in the greater part of the area, and it expands from 5 feet to as much as 30 feet. The position of this coal is, on the average, about 26 feet below the more persistent Middle Kittanning coal and about 53 feet above the well-defined Putnam Hill limestone. Lying directly, or only a few feet above the Lower Kittanning, is a bed of nodular limestone with which is associated scattered deposits of flint clay. The Lower

Kittanning coal or its clay is found above drainage in Newton, Clay, Brush Creek, Harrison, Springfield, Hopewell, Wayne, Falls, Muskingum, Cass, Washington, Madison, Adams, and Monroe townships, but the areas in some of these are very small. In general the coal is poorly developed as it is represented in most of the area by only a soot streak. The bed has sufficient thickness for drift mining in small areas north of Zanesville in Washington Township, south of this city in Wayne Township, and south of Fultonham in Newton Township. Thin local deposits seldom exceeding 1 foot 8 inches in thickness are also present in Brush Creek, Madison, and Monroe townships. The clay, however, is more widely distributed, and is found with few exceptions in the localities where due. The bed is variable in both thickness and composition, but the clay is always of the plastic variety.

Newton Township.—The Lower Kittanning coal or its associated clay is found only on the highest ridges and knobs in the western part of Newton Township, but owing to the dip of the rocks to the east and south the bed lies about midway up the slope of the hills in the eastern part. The only productive area within this township lies in the vicinity of Fultonham, where this coal has been mined for many years to supply the local needs. The following section, taken in the mine of L. G. Harkness, located in Section 23, is representative of the coal in the area:

		Ft.	In.
Shale and covered		25	--
Clay and covered		4	--
Coal, bony, with shale	*Lower Kittanning*	--	4
Coal, good		--	9
Coal, bony		--	1
Coal, good		3	5
Clay, plastic		2	--

Other small wagon mines are operated in this vicinity, but they show no new features with respect to the coal. The associated clay is very steady across the township and is on the average between 4 and 6 feet in thickness. Where the coal is absent the Lower Kittanning clay merges with the overlying Oak Hill clay, which also has excellent thickness in most of the area. These relations are shown in the following section, taken at the mines of the Hydraulic Press Brick Co., located in Section 34:

		Ft.	In.
Coal, shaly		--	1
Clay, plastic, dark-gray	*Oak Hill*	5	--
Clay, plastic, with nodules of *Hamden* limestone more than 1 foot in thickness		2	--
Clay, plastic		1	--
Clay, flint, light-gray		3	--
Coal smut, *Lower Kittanning*		--	1
Clay, plastic, light to gray, *Lower Kittanning*		6	8

Clay Township.—Both the Lower Kittanning coal and clay are above drainage east of Roseville, and for about 2 miles south of this town along Elk and Riders runs. The coal is seldom represented by more than a soot streak, but the clay has good thickness and continuity. In conjunction with other material this clay is worked for ceramic purposes by the Roseville Paving Brick Co.

Brush Creek Township,—In Brush Creek Township the horizon of the Lower Kittanning member is above drainage along the Muskingum River and along Brush Creek and its tributaries as far south as Cannelville. The clay has good volume and quality, but the coal is everywhere thin, usually being only an inch or two in thickness.

Harrison Township.—Owing to the general dip of the rocks to the south and east the Lower Kittanning members in Harrison Township pass below drainage on the Muskingum River near Duncan Falls. The bed lies along the flood plain and is therefore seldom observed. The few exposures noted indicate that the clay has fair thickness, but that the coal is absent.

Wayne Township.—The Lower Kittanning coal in Wayne Township is above drainage along the Muskingum Valley as far south as Duncan Falls, but only in small areas has the bed sufficient thickness to be mined, the best of these areas being in Salt Gum and Howards Lane hollows south of Zanesville, and in Section 14. The associated clay is very persistent across the township and has fair thickness. Along the river road in the southern part of Zanesville, Michael Arthur has opened a mine in the Lower Kittanning coal, which measures 2 feet 2 inches in thickness. In this locality the coal lies 24 feet above the Putnam Hill limestone. South of this in Salt Gum Hollow the Lower Kittanning coal is mined in a small way on the land of Alexander Carson. The structure of the bed is shown below:

		Ft.	In.
Shale, gray		8	--
Coal	*Lower Kittanning*	1	10
Clay		1	5
Coal, impure		1	1
Clay with parts covered		11	2

In this region the roof of the coal is shale and not Oak Hill clay or Hamden limestone, which is the exception to the rule in Muskingum County. The thick clay parting between the two coal benches impairs the value of the coal bed, as the fuel when mined is dirty and the quantity of refuse which must be handled is large. This parting varies considerably in thickness, however, and is stated to be only a few inches in places.

In Howards Lane Hollow small quantities of Lower Kittanning coal have been mined along the stream bed on the property of Henry Mainer. The coal is in one bench, the measurements of which were

from 1 foot 4 inches to 1 foot 8 inches. Its position at this place is about 50 feet below the Middle Kittanning coal and about 22 feet above the Putnam Hill limestone, which intervals are both somewhat abnormal. The associated clay is from 3 to 6 feet in thickness, and of the usual plastic character. The best pocket of Lower Kittanning coal in Wayne Township is found in a small area in Section 14, where the bed is regularly mined for local consumption on the property of Henry Young. The record follows:

		Ft.	In.
Limestone, shale and clay, *Hamden*		5	8
Coal	*Lower Kittanning*	1	--
Pyrite, irregular		--	1
Coal		2	1
Pyrite, irregular		--	1
Coal		1	3
Clay, plastic		4	--

The coal in this mine was sampled for chemical analysis. The member is reported to have good thickness, also on the adjoining farms, but the total area appears to be only a few hundred acres. The roof of the coal in this region is the Hamden limestone, which is rather firm and strong. In the remainder of the township no coal of value was found on this horizon, but the clay averages 4 or 5 feet in thickness and is of good quality.

Springfield Township.—The areas of the Lower Kittanning members in Springfield Township are confined to the main ridges and their highest laterals. Only a marking of the coal is present, but the clay is well represented. It is plastic in character and has been worked to a small extent for ceramic ware, near Brighton, Putnam, and South Zanesville. The clay was also recently mined by drifting on the farm of B. Fillmore for the Zanesville potteries. The clay is of good quality and about 5 feet thick.

Hopewell Township.—The Lower Kittanning members, in Hopewell Township, are present only on the high ridges and knobs in the vicinity of Coaldale and Mt. Sterling. The interval from this coal to the Middle Kittanning is 20 to 30 feet. In many places the Hamden limestone is all that separates the Oak Hill clay from the Lower Kittanning clay, so that the total thickness of clay in many places exceeds 20 feet. This clay was formerly worked for stoneware pottery in small country shops in several localities in Hopewell Township.

Falls Township.—In the western part of Falls Township, the Lower Kittanning members are confined to the high knobs and ridges, but owing to the dip of the rock to the east, the beds lie well down the slopes of the hills near the Muskingum River. The coal is absent except for a soot streak or for a few inches of dark carbonaceous clay. The clay, however, is well developed and is of the usual plastic character. Along the ridge road, just south of the Falls-Muskingum

township line and west of Bartlett Run, this clay is partially replaced by a clay-bond sandstone. Further, it is often so merged with the overlying Oak Hill clay, that the two beds are separated with difficulty along the outcrop.

Washington Township.—One of the best areas of Lower Kittanning coal in Muskingum County is found along Mill Run and near Wortley in Washington Township. The bed at this place has excellent thickness, in many places being 4 feet, and has been mined for many years for a part of the local fuel supply. The bed is somewhat regularly broken into three coal benches by two partings. The upper parting, usually the thicker of the two, is a pyritiferous shale; whereas the lower one is a clay shale in which the cutting is usually done. Further, the main bed is often overlain by a few inches of bone coal, which is usually removed in mining. The fuel is of fair quality and is well liked for domestic purposes. The Hamden limestone, often containing many large bivalve shells, lies either directly on or only a foot or so above the coal. The interval from the base of the Lower Kittanning coal to the base of the Middle Kittanning member is from 25 to 35 feet, the usual interval being about 30 feet. The Lower Kittanning clay in this locality is generally thin and siliceous, seldom exceeding 4 feet in thickness. In the mine of W. L. Barker, on Mill Run, the following measurements were made of the coal:

		Ft.	In.
Shale, calcareous, with limestone		4	--
Coal, bony	*Lower Kittanning*	--	9
Coal, with pyrite bands		--	6
Coal, good		2	6
Coal, impure		1	--
Clay		2	--

Near Wortley the Lower Kittanning coal is regularly mined at several places. The following section is representative of the coal in the area:

		Ft.	In.
Shale, calcareous, fossiliferous	*Hamden*	4	--
Limestone		--	4
Shale, dark, calcareous, fossiliferous		1	1
Coal, bony	*Lower Kittanning*	--	4
Coal, good		1	7
Shale		--	¼
Coal, good		2	7
Clay		2	--

In this district the coal area will not exceed 1½ square miles and much of it has been worked out. Small patches of coal, usually thin, were observed north of Wortley to the Baltimore & Ohio Railroad, where the bed again expands to about 4 feet. It is mined at this place by the Coaldale Coal Mining Co. for railroad shipment. Near the Hague School in Section 8, the Lower Kittanning coal is present on

the land of W. H. Bowers. The bed is 1 foot 8 inches in thickness and is without well-defined partings. Its position is 22 feet below the Middle Kittanning coal. In the northern part of the township the coal is seldom more than a few inches in thickness, but the clay averages from 4 to 8 feet.

Muskingum Township.—But little needs be said regarding the Lower Kittanning members in Muskingum Township as the beds are present only on the main ridges in the eastern part of the area. The coal is practically wanting, but the clay varies from 5 to 12 feet in thickness. The clay in the upper part of the bed is of much the best quality as it contains less silica and other impurities than that in the lower part. It is light-colored and very plastic. Thick beds of this clay are exposed along the ridge from the Sandy Ridge School to Stringtown. This deposit was formerly worked by small country potteries for stoneware. The weathered clay along the outcrop was regarded as the best for this purpose. The Hamden limestone is generally present just above the clay, but the Oak Hill clay lying above the limestone was seldom observed.

Cass Township.—On the high knobs of the main ridge in the eastern part of Cass Township, there are small areas of Lower Kittanning clay overlain by an inch or two of rotten coal or dark clay. These beds also occur on a few of the highest knobs along the ridge known as the Highlands, as well as along Irish Ridge north of the preglacial Newark River Valley. Along these ridges the place of the Lower Kittanning coal is also marked by only a few inches of dark clay, which along the outcrop soon loses its identity. At other places the Oak Hill flint and plastic clay are present only above the Hamden limestone, or if the limestone is absent it lies directly on the Lower Kittanning clay, under which conditions it is difficult to differentiate the two members. The thickness of the combined deposits often exceeds 20 feet.

Madison Township.—In Madison Township the Lower Kittanning coal was formerly mined in a small way in the hollow near the Adams Mills bridge across the Muskingum River. The bed is reported to be from 3 to 4 feet in thickness, but the area is stated to be small. With this exception no coal of value was found in the township. The clay, however, is very persistent, and has good ceramic qualities. The following section, taken along the road south of the crossroads on Symmes Creek, shows the general conditions of the Lower Kittanning members and their relation to adjacent beds of importance:

		Ft.	In.
Clay, dark, carbonaceous	*Oak Hill*	--	4
Clay, dark, plastic	*Oak Hill*	7	--
Coal smut, *Lower Kittanning*		--	2
Clay, light, plastic		5	--
Shale and covered		44	--
Limestone, *Putnam Hill*		4	6

In some localities the Lower Kittanning clay thickens to as much as 10 feet, but it is then usually somewhat siliceous near the base. This clay was formerly worked by country shops for the manufacture of stoneware, such as jugs, crocks, and jars.

Adams Township.—The Lower Kittanning coal and clay extend from Madison Township into Adams Township for about 1 mile along Symmes Creek and along its large tributaries, South Branch and North Branch, before they pass below cover. The beds are also above drainage along Wills Creek across the northern boundary. The coal is seldom represented by more than a soot streak, whereas the clay has fair volume, varying from 3 to 10 feet in thickness.

Monroe Township.—Owing to the pronounced anticline or eastward rise of the rocks in Monroe Township, the Lower Kittanning coal, with its associated clay, is above drainage along Wills Creek in the vicinity of Marquand Mill and along White Eyes Creek from the Muskingum-Coshocton county line to Otsego. In the vicinity of Marquand Mill the coal lies near the level of the flood plain, and has been mined in a small way by stripping. The thickness of the bed is reported to be about 1 foot 8 inches, and the coal to be of good quality. The interval at this place from the Lower Kittanning coal to the Middle Kittanning coal is approximately 25 feet. Along White Eyes Creek this coal is inconspicuous, seldom being more than a smut streak, whereas the clay usually has normal volume and fair quality. Both the overlying Hamden limestone and Oak Hill clay are usually absent in this area.

Economic Value of Lower Kittanning Coal

The Lower Kittanning coal in Muskingum County is only of local importance as the deposits of good thickness are confined to three small areas, the first southwest of Fultonham in Newton Township, the second northeast of Zanesville in Washington Township, and the third south of Zanesville in Wayne Township. Owing to the patchy character of the deposits it is difficult to estimate the area of good coal, but this will not exceed 4 square miles. As these deposits have been worked for many years, a considerable part of the area is now exhausted, and, owing to the careless methods of mining, other parts are rendered practically inaccessible. Therefore, the quantity of coal yet available is not large. The mining conditions are usually somewhat poor as the roof is often tender shale or nodular limestone overlain by clay, and as the floor is nearly everywhere a soft plastic clay. Under such conditions the yield of fuel is below normal and the danger to the workman considerably increased.

The general character of the Lower Kittanning coal in Muskingum County is shown in the following analyses:

"Its composition as sampled from Harper's bank for the Survey by Mr. E. C. Downerd and analyzed by Professor Lord is as follows:[1]

Lower Kittanning coal, No. 5, Zanesville.

Moisture	4.93
Volatile matter	39.72
Fixed carbon	49.96
Ash	5.39
Total	100.00
Sulphur	3.45"

The Lower Kittanning coal was sampled by R. E. Lamborn and the writer, in the mine of L. G. Harkness, which is located just west of Fultonham. At this place the coal had only about 30 feet of cover and was slightly weathered along the joint planes. The mine was dry and the sample was taken under good conditions. The chemical work was done by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	68.40	Moisture	7.96
Hydrogen	5.54	Volatile matter	39.18
Oxygen	16.30	Fixed carbon	46.87
Nitrogen	1.37	Ash	5.99
Sulphur	2.40		
Ash	5.99		

Calorific value { 6,893 calories. 12,407 B. t. u.

Air drying loss of moisture, 2.6 per cent.

The Lower Kittanning coal, in the area southeast of Zanesville, was sampled at the mine of Henry Young, in Section 14, Wayne Township, by R. E. Lamborn and the writer. The sample was taken at the head of the entry where the coal was under deep cover and was bright and fresh. The mine was dry. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	66.67	Moisture	5.87
Hydrogen	5.38	Volatile matter	41.52
Oxygen	13.30	Fixed carbon	43.91
Nitrogen	1.16	Ash	8.70
Sulphur	4.79		
Ash	8.70		

Calorific value { 6,771 calories. 12,188 B. t. u.

Air drying loss of moisture, 1.6 per cent.

Fusion temperature of ash { incipient 1,109° C. complete 1,139° C.

[1]Geol. Survey Ohio, Vol. V, pp. 872-73.

The Lower Kittanning coal is a free-burning fuel with moderate heating qualities. It tends more towards the coking type and is more lasting than the Middle Kittanning coal. The bed often contains several soot bands or layers of "mother coal". The sulphur occurs in the form of pyrite nodules or irregular layers and is somewhat high. The ash is usually rather high and light-gray in color. It fuses at moderate temperatures to a spongy clinker. The coal is well liked for general house use and is considered a fair steaming fuel. It burns with a long flame, which is of advantage for ceramic purposes. For glaze work the high sulphur in the coal is objectionable. The operations are all wagon mines of small capacity.

Economic Value of the Lower Kittanning Clay

The volume of Lower Kittanning clay, easily available in Muskingum County, is large, being amply sufficient to last the ceramic plants working this grade of material for many generations. The bed varies from 3 to 12 feet in thickness, but averages about 6 feet. The yield per acre for such a deposit where all is available is approximately 20,400 tons, or enough to make 5,800,000 standard building brick. In many localities large quantities of this clay, as well as the overlying Oak Hill clay, may be mined by stripping at a low cost, as the beds extend along the ridges or along the hillsides with but little covering. The Lower Kittanning horizon in Muskingum County yields only a plastic clay, which, with few exceptions, is of fair quality. The lower part of the deposit is in many places somewhat siliceous and gradates into a light clay-bond sandstone. On the whole the clay is very free from ferruginous or siliceous concretionary matter and from notable quantities of pyrite and carbon. The general composition of the Lower Kittanning clay is shown in the following analysis made by Prof. D. J. Demorest from a sample taken in the mine of the Hydraulic Press Brick Co., at Roseville, by R. E. Lamborn and the writer:

Silica, SiO_2	53.04
Alumina, Al_2O_3	26.70
Ferric oxide, Fe_2O_3	3.00
Lime, CaO	.94
Magnesia, MgO	.93
Titanic oxide, TiO_2	1.30
Sodium oxide, Na_2O	.58
Potassium oxide, K_2O	.77
Loss on ignition	12.82
Total	100.08

The softening point is about Cone 26 or 3,000° F., and its final fusion point is not far above this temperature. This clay vitrifies to a good dense body at Cone 4 or 2,210° F. The plasticity is excellent and the shrinkage both drying and burning is about normal,

being about $1\frac{1}{4}$ inches per foot. At the early stages of vitrification under oxidizing conditions, the body has a light-buff or cream color, but under reducing conditions it is a light-gray or bluish-gray. At higher temperatures the bodies become considerably darker in each case.

The Lower Kittanning clay has a number of ceramic uses, the most important of which are for stoneware, building brick, sewer pipe, fireproofing, paving brick, and fire brick. It is also employed as bonding clay in the manufacture of art pottery, Rockingham and yellow ware, mosaic tiling, and saggers. In Muskingum County it is used mainly in conjunction with the Oak Hill, Middle Kittanning, or Tionesta clays for the manufacture of stoneware, building brick, and paving block. For stoneware the clays are blunged, screened, filter-pressed, partially dried, and then tempered and pugged ready for the workmen who form it into ware by "jiggering." The green ware is partially dried in the molds on open racks, then removed and finished. From here it is taken to the hot room where it is completely dried or nearly so before it is removed and the slip glaze applied by dipping. After the glaze is allowed to dry, the ware is removed to the kiln where it is set and burned. In some cases the ware is salt-glazed in the kiln during the latter part of the burn. This clay is reported to make first-class ware and is used to some extent by several potteries in the region. The Lower Kittanning clay in conjunction with other clays and shales is used to some extent in the manufacture of paving block by the Roseville Paving Brick Co. at Roseville, and by the National Paving Brick Co. at South Zanesville. In these factories the clay is used for bonding the more siliceous shales. This clay with the overlying Oak Hill clay is used by the Hydraulic Press Brick Co. at Roseville, in the manufacture of buff and iron-mottled building brick. The ware is well vitrified, has good structure, and has a pleasing appearance.

HAMDEN LIMESTONE AND ORE

The third well-defined limestone stratum in ascending order in the Allegheny formation of Muskingum County is one which in this report is called Hamden, retaining the name applied to an iron ore which has excellent local development in southern Vinton and northern Jackson counties, and which has been described in Bulletin 20. The iron ore in these southern counties and the limestone and ore of Muskingum County are on the same stratigraphic horizon. The member lies either directly on or only a few feet above the Lower Kittanning coal and just below or often within the body of the Oak Hill clay. In Jackson County stray nodules of impure limestone were also found on this horizon. Where best developed in Muskingum County it is a hard, dense limestone of a dark-gray or occasionally nearly black color, and of fair purity. As a usual thing, however, it is decidedly ferruginous, the iron oxides being in such quantities that the lime-

stone along the outcrop has a yellow or brown color. In fact, in many places the member is represented by an impure limonite ore, or by a mixture of ore and limestone. Both the limestone and ore are usually more or less nodular in structure even where the bed is 1 foot or more in thickness. The Hamden member in Muskingum County is everywhere fossiliferous, large bivalves being especially common in some localities. It affords a rich field for the paleontologist.

The Hamden limestone and ore are best developed in Brush Creek, Harrison, Hopewell, Falls, Wayne, Washington, Muskingum, and Cass townships, although they occur also in Clay, Newton, Springfield, Madison, Adams, and Monroe townships. Owing to the fact that many sections showing the position of this member have already been given only some of the best exposures will be described. Near the mouth of Sycamore Run, on the Mrs. Frank Stevens property, in the northern part of Harrison Township, the following record was secured:

		Ft.	In.
Shale		8	--
Coal, bony	*Middle Kittanning*	--	3
Coal, good		1	2
Shale, hard		--	1½
Coal, good		1	4
Clay, light, and covered		4	--
Sandstone		7	--
Shale with iron ore concretions		7	6
Coal		--	2
Clay, dark, impure	*Oak Hill*	4	--
Clay, light, plastic		4	--
Limestone, irregular, nodular, *Hamden*		1	6

The Hamden limestone at this place varies from a few inches to 2 feet or more in thickness. The nodules are very irregular in shape and size and are overlain by the Oak Hill clay. The limestone is sparingly fossiliferous and very impure, containing both siliceous and ferruginous matter in notable quantities. Nodular deposits are rather common along Brush Creek, and along the Muskingum River in Brush Creek Township, and along Elk Run and its tributary Riders Run, in Clay Township. The position of the bed is at or near the base of the Oak Hill clay, and just above the horizon of the Lower Kittanning coal. The general character of the deposit in Newton Township is shown by the following measurements, taken at the mine of the Hydraulic Press Brick Co., in Section 34:

		Ft.	In.
Coal, shaly		--	1
Clay, plastic, dark-gray	*Oak Hill*	5	--
Clay, plastic, with large irregular nodules of *Hamden* limestone		2	--
Clay, plastic		1	--
Clay, flint, light-gray		3	--
Coal smut, *Lower Kittanning*		--	1
Clay, plastic, light to gray		6	8

As shown by the above section, the Hamden member in this locality is bedded within the body of the Oak Hill clay. Some of the limestone nodules were more than 1 foot in thickness. They are ferruginous, siliceous, and sparingly fossiliferous. The Hamden member is rather steady across Springfield Township, but it is everywhere of the nodular form bedded in or at the base of the Oak Hill clay and just above the horizon of the Lower Kittanning coal.

Scattered deposits of the Hamden limestone and ore were observed along the main ridges in the central and in the eastern parts of Hopewell Township. Along the road just south of Mt. Sterling the nodules of limestone are 4 to 10 inches in thickness. The limestone is very fossiliferous and is decidedly ferruginous, the weathered pieces having the appearance of an iron ore.

In Falls Township the Hamden member, represented by either limestone or iron ore, is present along the main ridge south of the Licking River and along that west of the Muskingum River. The following rocks were exposed along the main ridge near the home of J. Smith, 3 miles west of Dillon Falls:

	Ft.
Coal blossom, *Middle Kittanning*	3
Clay	3
Shale and covered	17
Limestone, *Hamden*	1
Clay, flint, with part covered, *Oak Hill*	3

At this place the Hamden limestone appears to be bedded in the body of the Oak Hill clay. The limestone is nodular, ferruginous, and siliceous, and is very fossiliferous. *Fusulina*, *Seminula*, and *Productus* are abundant. The nodules vary in thickness from a few inches to nearly 2 feet. In the eastern part of Falls Township the bed is generally thin and in places absent.

One of the most massive exposures of Hamden limestone in Muskingum County is found at the coal mine of Henry Young, which is located in Section 14, Wayne Township. The record follows:

		Ft.	In.
Sandstone, shaly		5	--
Clay with ferruginous limestone nodules	*Hamden*	1	8
Limestone, nodular, ferruginous, fossiliferous	*Hamden*	--	6
Shale, gray, very fossiliferous	*Hamden*	3	--
Limestone, blue, irregular, very fossiliferous	*Hamden*	--	6
Coal	*Lower Kittanning*	1	--
Pyrite parting, irregular	*Lower Kittanning*	--	1
Coal	*Lower Kittanning*	2	1
Pyrite parting, irregular	*Lower Kittanning*	--	1
Coal	*Lower Kittanning*	1	3
Clay, plastic		4	--

In this locality the Hamden limestone forms the roof of the Lower Kittanning coal, and both the limestone and interbedded shale are very fossiliferous. The Oak Hill clay is either absent or is represented by

the 1 foot 8 inches of clay lying just below the shaly sandstone. The opportunity here for collecting is especially good. In Salt Gum and Howards Lane hollows, both the Hamden limestone and Oak Hill clay are generally wanting, but they are present east of Zanesville at the mines of the Burton-Townsend Brick Co. At these mines nodules of Hamden limestone are bedded in the body of the Oak Hill clay which has a thickness of 12 feet. On Mill Run, and near Wortley in Washington Township, the roof of the Lower Kittanning coal is the Hamden member, which is made up of fossiliferous limestones and shales measuring 2 to 4 feet.

Scattered deposits of Hamden limestone or its equivalent iron ore are found along the high ridges in the eastern half of Muskingum Township. It is everywhere nodular in structure and ferruginous in character. Fossils are abundant in some deposits, but are wanting or nearly so in others. In the eastern part of Section 3 the Hamden is a thick but nodular limestone of fair purity and of a dark color, parts being nearly black. Along the main ridge and its spurs from the Sandy Ridge School to Stringtown, thin deposits of Hamden limestone are present in local areas. The Oak Hill clay, closely associated with this limestone, is generally wanting, as is also the Lower Kittanning coal.

In Cass Township very good exposures of the Hamden limestone are present along the high ridge known as the Highlands, and extending across the area south of the old Newark River Valley. Other exposures also occur along the main ridge in the eastern part of the township. West of Dresden 1 mile the limestone is of the usual character, nodular, ferruginous, and fossiliferous. Along the main ridge west of the Elberson School this bed has excellent thickness and purity. A section taken here follows:

	Ft.
Limestone, nodular, gray, *Hamden*	3
Clay, light, *Lower Kittanning*	5
Shale	10
Limestone, *Ferriferous*	2

The Hamden limestone in this locality has a gray color and is notably fossiliferous, *Seminula* being especially abundant. West of this the deposit thins somewhat and becomes more ferruginous. A few patches of this limestone were also observed on Irish Ridge in the northern part of Cass Township. The member is rather constant in Madison and Adams townships, but where observed it is of the nodular form bedded in or just below the Oak Hill clay. The thickness of the limestone nodules in places is as much as 1 foot 6 inches.

The Hamden limestone or its equivalent iron ore is poorly represented in Monroe Township. The horizon is above drainage along Wills Creek near Marquand Mill in the northwestern part and along White Eyes Creek in the northeastern part. Only occasional nodules of limestone embedded in clay were observed.

Economic Value of Hamden Limestone and Ore

Neither the Hamden limestone nor its derivative iron ore adds materially to the mineral resources of Muskingum County, as the deposits are local and widely scattered and as the thickness of the beds is small and the quality of the materials poor. Small quantities of this ore obtained by stripping along the outcrop were used by the charcoal furnaces that once operated in this county. Owing to the inferior quality of the ore its value at present is trifling. The limestone, however, may be employed for road building in the immediate areas in which it is found. Along some of the ridges the quantity of this material is sufficient to build the roads that traverse them.

In Muskingum County the Hamden limestone is purest and best developed along the ridge known as the Highlands in southern Cass Township. A sample of the material taken near the Elberson School in Section 14 and analyzed by Prof. D. J. Demorest gave the following results:

Silica, SiO_2	1.86
Alumina, Al_2O_3	.52
Ferric oxide, Fe_2O_3	.82
Titanic oxide, TiO_2	trace
Lime, CaO	53.68
Magnesia, MgO	.76
Phosphorus, P	.039
Sulphur, S	.15

Converting these components to their mineral analysis, the results are approximately as follows:

Clay, $Al_2O_3.2SiO_2,2H_2O$	1.31
Quartz, SiO_2	1.25
Pyrite, FeS_2	.28
Limonite, $2Fe_2O_3,3H_2O$	.74
Titanic oxide, TiO_2	trace
Calcium phosphate, $3CaO.P_2O_5$	.20
Calcium carbonate, $CaO.CO_2$	95.66
Magnesium carbonate, $MgO.CO_2$	1.60.
	101.04

The above analysis shows that the Hamden limestone in this locality is of excellent quality and may be used successfully for agricultural purposes either in the raw or calcined states. Large quantities of the stone are readily available as the bed outcrops near the summit of the main ridges.

OAK HILL CLAY

Stratigraphy and Extent

The Oak Hill clay, which is of considerable economic importance in Jackson County, has good thickness in local areas in Muskingum County. This clay and the Hamden limestone member appear to

have been laid down during the same swamp or shallow water period, as the limestone or its equivalent iron ore lies either at the base of the clay or in places within the body of the deposit. In many localities this clay merges with the underlying Lower Kittanning clay as the Lower Kittanning coal and Hamden limestone are both wanting. In other parts of the area, however, the two clay beds are separated by a few feet of shale or sandstone. Further, in places the usual shale or sandstone parting separating the Oak Hill clay from the overlying Middle Kittanning clay is wanting or is so thin that it is negligible in mining. The total thickness in local areas of these coalesced or thinly separated clays, the Lower Kittanning, the Oak Hill, and the Middle Kittanning, is often 20 to 40 feet and the general character of the clays, excepting a part of the Oak Hill which is flinty, is much the same.

The distribution of the Oak Hill clay is much the same as the Lower Kittanning, being found above drainage in Clay, Brush Creek, Newton, Hopewell, Springfield, Wayne, Harrison, Falls, Muskingum, Washington, Cass, Madison, Adams, and Monroe townships. In some of these townships, however, the areas of clay are small or the deposits are local and scattered. Owing to a similarity of conditions no additional sections need be given.

The Oak Hill clay is found above drainage along Brush Creek and its tributaries in Brush Creek Township. The bed is rather steady and is closely associated with the Lower Kittanning clay, these members being separated in many places by only a few inches of impure coal or by this and the Hamden limestone or iron ore. The deposits are usually made up of plastic clay in which more or less flint clay is interbedded. The clay is present above drainage along the Muskingum River in Harrison Township as far downstream as Duncan Falls, but owing to the heavy covering along the valley, is seldom exposed for measurement. In Clay Township the member is present in the vicinity of Roseville and south of this along Elk and Riders runs. The thickness and character of the clay is much the same as it is in Brush Creek Township. The total area of Oak Hill clay in Newton Township is large as the bed is found near the summits of all the main ridges in the western part, and owing to the dip of the rocks, well down the slopes of the hills in the eastern part. In conjunction with the Lower Kittanning and the Middle Kittanning clays and shale it is worked north of Roseville for the manufacture of stoneware, building brick, and paving block. The stratum varies from 3 to 10 feet in thickness, but averages approximately 5 feet. Plastic clay is the usual representative, although flint clay is also present in many localities.

The Oak Hill clay is rather persistent along the main ridges in all of Springfield Township, but it is usually plastic in character. The

bed is wanting in parts of Wayne Township as its place is taken by shaly sandstone. Where present, however, the clay is often separated from the Lower Kittanning coal by several feet of shale and it is usually of the plastic type only. A section taken at the No. 2 plant of the Burton-Townsend Brick Co., and given below, shows the clay with excellent thickness:

		Ft.	In.
Coal, bony, hard		--	2
Clay, plastic	*Oak Hill*	5	--
Clay, part flint with some nodules of *Hamden* limestone	*Oak Hill*	7	--
Coal smut, *Lower Kittanning*		--	1
Clay, light, plastic		7	--
Clay, very siliceous		7	--

The Oak Hill clay is used at this plant for bonding material in the manufacture of paving block. The flint clay is present in irregular masses which lie in the lower part of the deposit. In Washington Township the member is above drainage along the Muskingum River and its tributaries and is rather steady throughout the area. In composition it varies from flint clay to plastic clay, the plastic, however, being the most common representative. Its usual position is directly above the Lower Kittanning coal, and from 15 to 25 feet below the Middle Kittanning member.

Along the ridges in the vicinity of Mt. Sterling and Coaldale, in Hopewell Township, local areas of both flint and plastic clay representing the Oak Hill member are present. Local deposits of flint clay from 3 to 8 feet in thickness are also present along these ridges. A good exposure of this variety was observed along the road about 1 mile north of Coaldale, where the following record was obtained:

		Ft.
Sandstone, shaly		9
Clay, light, plastic	*Oak Hill*	1
Clay, light, flint	*Oak Hill*	5
Shale and covered		6
Horizon of *Lower Kittanning* coal.		
Clay, dark, carbonaceous, plastic	*Lower Kittanning*	1
Clay, light, plastic	*Lower Kittanning*	2

The above measurements were duplicated at other places in Hopewell Township. The Hamden limestone is usually present at or near the base of the clay, and the Lower Kittanning coal, marked by a smut streak, is separated from it by only a few feet of strata at most. The common interval from the base of the clay to the base of the Middle Kittanning coal is from 20 to 25 feet.

Falls Township contains small areas of Oak Hill clay on the high knobs of the main ridges south of the Licking River, and on those of the ridge that extends north from Zanesville and lies west of the Muskingum River. The horizon of this clay is confined to the high

ridges and knobs in the eastern half of Muskingum Township, but the stratum is far from being steady, as it is replaced in many places by sandstones or shales. Where present the clay is generally plastic in character, and so merged with the Lower Kittanning clay that the two beds are difficult to differentiate, especially along the outcrop. The thickness of the deposit is from 3 to 8 feet.

In Cass Township the Oak Hill clay is more persistent and better developed, but the deposits are confined to isolated knobs along the main ridges. Flint clay is also a more common representative. In places the entire interval from the horizon of the Ferriferous limestone to the Middle Kittanning coal is made up of the Lower Kittanning, Oak Hill, and Middle Kittanning clays, with but a few feet of shale, sandstone, and limestone intervening. In Madison Township this clay is a common stratigraphic feature and is above drainage in nearly all of the area. In many places flint clay from 2 to 6 feet in thickness is present with the plastic material. The following measurements were obtained along the road on the South Branch of Symmes Creek, near the Fritz School:

		Ft.
Shale, dark, carbonaceous		1
Clay, plastic		2
Limestone, irregular, nodular, ferruginous, *Hamden*	*Oak Hill*	1
Clay, flint		6

At other places the proportion of flint clay in the bed is much less than it is in this locality, but the thickness of the member is considerably greater. With few exceptions in this township the Hamden limestone is bedded within the clay.

Deposits of Oak Hill clay are found along the courses of Symmes Creek and its larger tributaries in the extreme western part of Adams Township, and along Wills Creek in the northern part. The clay is generally plastic in character and lies close to the Middle Kittanning clay. The exposures of the Oak Hill member in Monroe Township are confined to a small area along Wills Creek in the vicinity of Marquand Mill, and to the valley of White Eyes Creek from the Muskingum-Coshocton county line to Otsego. This clay is not persistent, as it is often replaced by other rocks. Where present the usual thickness of the bed is about 5 feet, and the general type of the clay is plastic. It lies directly on or only a few feet above the horizon of the Lower Kittanning coal and from 15 to 25 feet below the Middle Kittanning member.

Economic Value of Oak Hill Clay

The Oak Hill clay adds materially to the ceramic wealth of Muskingum County, although it is of less value than either the Lower Kittanning or the Tionesta clays. Both flint and plastic clays are found on the horizon, but the quantity of the flint clay is far less than that of the plastic. Both clays vary in color from light-gray to dark-gray

A—Shales in the lower part of the Allegheny formation used for the manufacture of building brick and paving block by the National Paving Brick Co. at South Zanesville. They lie between the Putnam Hill limestone shown in the foreground under the bushes at the right and the Lower Kittanning clay shown in the background at the top of the chute.

B—Shale pit of the Burton-Townsend Brick Co. at Zanesville. The floor of the quarry is the Middle Kittanning coal and the top is only a few feet below the Bolivar clay.

PLATE VII.

A—A mass of Ferriferous or Vanport flint broken from the bed on Flint Ridge. The full thickness is not exposed.

B—Lower Freeport limestone on Duncan Run, Harrison Township.

or to nearly black, the increased coloration being due largely to organic matter. The range in composition is rather wide, especially in regard to the silica content. Also owing to the influence of the Hamden limestone member, which lies at the base or within the body of the Oak Hill clay, the variation in the contents of iron oxide, lime, and magnesia is also large along this zone. Pyrite is a common constituent along the plant markings, especially prominent near the top of the deposit.

The general composition of the Oak Hill clay is shown by the following analysis made by Prof. D. J. Demorest from a sample taken at the mine of the Hydraulic Press Brick Co. at Roseville:

Silica, SiO_2	55.60
Alumina, Al_2O_3	24.26
Ferric oxide, Fe_2O_3	4.22
Lime, CaO	1.00
Magnesia, MgO	1.36
Titanic oxide, TiO_2	.88
Sodium oxide, Na_2O	.17
Potassium oxide, K_2O	1.86
Loss on ignition	10.74
Total	100.09

The bed sampled at this place contained both flint and plastic clay, and was about 11 feet in thickness. Nodular Hamden limestone lying about 4 feet from the base of the clay was carefully excluded. On the whole the sample should be representative of the main volume of the Oak Hill clay in Muskingum County.

The total fluxes are so high that the clay may be rated as only a second-grade refractory material. The soft clay has good plastic properties, which are easily developed by weathering, or by simply working with water. The natural bonding power of the flint clay is low, but this is considerably increased by wet pan grinding, or by extensive weathering of the raw clay, or aging of the prepared muds. The drying and fire shrinkages of these clays are about normal, being about $1\frac{1}{4}$ inches per foot. The flint clay in some of the best deposits, if properly selected, and if bonded with Lower Kittanning plastic clay, will make a fire brick of moderate refractory power, especially useful for general work such as ceramic kilns, boiler settings, mill brick, etc. The plastic clay on the Oak Hill horizon is generally inferior in refractory qualities to that on the Lower Kittanning horizon as it is higher in fluxing impurities. It may be successfully utilized, however, for building brick or fireproofing.

The average thickness of the deposits of Oak Hill clay in Muskingum County is about 5 feet. The variation, however, is from 2 to 15 feet. Owing to the stratigraphic position of this clay, lying as it does between the Lower Kittanning and the Middle Kittanning clays, and being separated from them in many places by only thin beds of shale or sandstone, it may be mined by stripping in many places in

conjunction with these clays, at a very low cost. Such mining is practiced in the vicinity of Roseville and South Zanesville, and the combined clays utilized in the manufacture of building brick and paving block. Where thus blended the Oak Hill clay is reported to work very satisfactorily. The total thickness of the three clay members, which may thus be mined from the same operation, is in many places between 25 and 40 feet, and is scarcely exceeded elsewhere in Ohio. This clay thus adds materially to the economic wealth of Muskingum County through the value of the clay itself, and through its direct association with other clay of ceramic value.

RED KIDNEY ORE

The Red Kidney ore, formerly worked for iron smelting in the charcoal furnaces of Jackson and Lawrence counties, deserves only passing mention in Muskingum County as the bed was observed at only a few places. The ore is bedded in the shale that forms the roof of the Oak Hill clay and lies only a few feet above the top of this clay stratum. It has a concretionary or kidney structure and a fair content of iron. The weathered ore along the outcrop has a dark-red or reddish-brown color, but where unoxidized it has the bluish-gray color characteristic of the ferrous carbonates. The thickness of the bed is generally between 2 and 6 inches, but the deposits are very local. The Red Kidney ore at present has no value in Muskingum County.

MIDDLE KITTANNING OR NO. 6 COAL AND CLAY

Stratigraphy and Extent

The coal bed upon which the industrial wealth of Muskingum County has been so largely built, and upon which its future so largely depends, is the Middle Kittanning or No. 6 coal. It also contributes the main supply of domestic fuel used in the county and furnishes some for outside markets. The Middle Kittanning horizon not only provides coal for the large ceramic industries for which the region is so widely known, but it also yields clays and shales upon which many of these operations are directly established. At present this interval is by far the most important in the county and it will retain this standing for many years.

The Middle Kittanning coal lies about 25 feet above the Lower Kittanning coal, 38 feet above the Ferriferous limestone, 81 feet above the more persistent Putnam Hill limestone, and 93 feet below the Upper Freeport or No. 7 coal. The bed is made up of three coal benches which are very persistent, but variable in thickness. The upper bench expanding from 2 inches to 1 foot 3 inches, but averaging about 7 inches, is made up of thin layers of dark shale, bony coal, and good coal. It seldom contains sufficient fuel to be of value and is usually left for the roof of the mine. The coal bench below this is of good quality and has an average thickness of 1 foot 1 1 inches. The maximum and

minimum thicknesses observed are 3 feet 2 inches and 1 foot 2 inches. The middle coal bench is separated from the lower one by a shale or clay parting varying from 1 to 3 inches in thickness, but averaging about 1½ inches. The lower coal bench, which seldom contains deleterious material, has a mean thickness of 1 foot 5 inches and has a range from 2 inches to 2 feet 2 inches. The general structure of the coal in this county is much the same as it is in the great field in Perry and Hocking counties.

The Middle Kittanning coal enters Muskingum County from Perry on the south, crosses the area in a northeasterly direction, and extends into Coshocton on the north and into Guernsey on the east. In Muskingum County the total area of the Middle Kittanning coal is about 195 square miles. This figure is based on the area above drainage and of known volume and that within easy shafting distance and of reasonably certain thickness and quality. The total area exhausted by mining is not more than 25 square miles, and that excluded by decayed coal along the outcrop and under shallow cover and by thin coal unprofitable for mining is not more than 20 square miles. This leaves approximately 150 square miles of fuel for utilization. Drill records also show this coal, at least in local areas, under deep cover in the townships Highland, Perry, Union, Salt Creek, Rich Hill, Bluerock, and Meigs, not included in the above estimate. The workable area is such that it may supply all the fuel demands, both domestic and industrial, for many years.

The Middle Kittanning coal is present above drainage in Clay, Newton, Brush Creek, Harrison, Wayne, Springfield, Hopewell, Falls, Washington, Muskingum, Cass, Madison, Adams, and Monroe townships. Although the bed has good thickness the areas of coal in the most western of these townships are small and therefore the deposit is relatively unimportant.

Clay Township.—In Clay Township east of Roseville and along Riders and Elk runs the Middle Kittanning coal is above cover and has been mined for many years. The average of all the measurements taken in this area shows the good coal in the two main benches to be 3 feet 6 inches in thickness and the parting separating them to be 1½ inches. The bed is very persistent in extent and the coal uniform in quality. Near the head of Elk Run, in Section 15, on the Valentine property the coal where measured in a small wagon mine has the following structure:

		Ft.	In.
Shale		5	--
Coal, bony	*Middle Kittanning*	--	7
Shale		--	2
Coal, good		1	6
Shale		--	2
Coal, good		1	10
Clay, siliceous		2	--

North of this, in Section 10, the Middle Kittanning coal has about the same thickness as shown by a measurement taken at the wagon mine of Thomas Rider, which is operated for domestic and factory fuel. In some mines in this section the coal is a few inches thicker than at the Rider mine. In the main, however, the bed is very steady. At the mine of the Elk Coal Co., in Section 3, the coal has the following structure and measurement:

		Ft.	In.
Shale		6	--
Coal, bony, roof coal	*Middle Kittanning*	--	6
Shale, black, carbonaceous		--	2½
Coal, good		1	9
Shale		--	1
Coal, good		1	8
Coal, bony		--	6
Clay		2	--

Other records taken in this section show about 3 feet 6 inches of good coal in the two main benches which are separated by a parting varying from 1 to 3 inches in thickness. The roof coal seldom contains any fuel of value. The member is also exposed in the northern part of Section 2 and in the eastern part of Section 1, where the measurements show approximately the same thickness as has been given in the preceding records. Only a small part of the coal area in Clay Township is exhausted although the bed has been worked for many years. The general mining conditions are good and the coal of marketable quality. The clay underlying the Middle Kittanning coal is from 2 to 10 feet in thickness and is employed for ceramic purposes.

Newton Township.—Both the Middle Kittanning coal and its associated clay are extensively utilized in Newton Township. The coal is mined for local use and for shipment, and the clay for ceramic purposes such as building brick and paving block. These beds are found only on the high ridges in the western part of the township, but owing to the general dip of the rocks they occur near the base of the hills in the eastern part. The coal is very steady and has good thickness in the entire area. A record of the rocks at the mines of the Hydraulic Press Brick Co., in Section 34, is given below:

		Ft.	In.
Shale, dark		3	7
Coal, bony	*Middle Kittanning*	--	6
Shale		--	3
Coal, good		1	7
Shale		--	2
Coal, good		1	9
Clay		1	2

The above section shows the general character of the roof of the coal in this locality which is of sufficient strength to allow a high yield of fuel. In a mine worked by this company the middle bench of coal is

1 foot 10 inches. The production is about 30 tons of coal per day. Along a stream bed on the land of B. Price, in the eastern part of Section 35, the Middle Kittanning coal showed 3 feet 3 inches of marketable fuel with 4 inches of bone coal above. Other measurements taken in this section show practically the same thickness. In a small mine on the property of J. L. Baughman, in Section 26, the coal has the following measurement:

		Ft.	In.
Shale, gray		1	9
Coal, bony		--	4
Shale, carbonaceous		--	4
Coal, good	*Middle Kittanning*	1	10½
Shale		--	1
Coal, good		1	8

The Middle Kittanning coal appears above drainage along Turkey Run and along Baughman Run in Section 25, but no good measurements were obtained. The coal is reported to be from 3 feet to 3 feet 6 inches in thickness. In the southern part of Section 25, on the E. L. Baughman property, the coal measures 3 feet, and is overlain with 8 inches of bone coal. The bed at this place lies close to drainage level and has a good strong roof. In the central part of Section 23, on the R. C. Burton land, the stratum has the following structure:

		Ft.	In.
Shale		10	--
Coal, bony		--	9
Coal, good		1	6
Shale	*Middle Kittanning*	--	1
Coal, good		1	4
Clay, siliceous		1	--

In the northern part of this section the massive sandstone lies directly on the upper block of impure coal, or replaces a part of it. The middle and lower benches of coal are each about 1 foot 6 inches in thickness. In the western part of the section also the thickness of good coal is about 3 feet, and the bed is overlain by a massive sandstone. At the Monitor mine of the Burton-Townsend Co., located in the northeastern part of Section 14, the structure and thickness of the coal are as follows:

		Ft.	In.
Shale		5	--
Coal, fair		--	5
Shale and impure coal		--	3½
Coal, good	*Middle Kittanning*	1	8
Shale		--	1½
Coal, good		1	7
Clay, siliceous		3	--

This general thickness of the middle and lower coal benches was observed at other places in Section 14. The upper coal bench, however,

is usually too bony to be of value. The measurements obtained in a stream bed on the A. Cusac land, in the western part of Section 13, show 2 feet 11 inches of coal, overlain with 8 inches of impure coal. At the country mine of W. H. Weller the coal has the following thickness and structure:

	Ft.	In.
Coal, reported thickness, *Upper Freeport*	4	--
Clay, shale, sandstone, and covered	90	--
Shale	10	--
Coal, bony	--	6
Coal, good	2	3
Shale	--	1
Coal, good	1	4
Middle Kittanning		
Clay, light	2	--

The Middle Kittanning coal is mined for domestic use in South Zanesville. At the mine of W. H. Weller, in Section 1, the record given below was obtained:

	Ft.	In.
Shale	10	--
Coal, bony	--	7
Coal, good	1	11½
Shale	--	1
Coal, good	1	4
Middle Kittanning		
Clay, light, siliceous	2	--
Sandstone	11	--
Clay, plastic, *Lower Kittanning*	6	--
Sandstone and covered	50	4
Limestone, *Putnam Hill*	1	9
Coal blossom, *Brookville*	--	2

This record shows the general intervals from the Middle Kittanning coal to other well-known members, some of which are especially prominent along the Muskingum River in the vicinity of Zanesville. The coal mined at this place is of good quality, and is delivered by wagon to South Zanesville. In the western part of the township the member is very steady, but the areas are small. It is mined in several places for domestic use.

Brush Creek Township.—In Brush Creek Township the Middle Kittanning coal is present above drainage along the Muskingum River, and along Brush Creek and its tributaries from its mouth to the vicinity of Cannelville. The bed is very steady in both extent and thickness. Around Cannelville this coal has been mined rather extensively for many years for railroad shipment, yet only comparatively small areas have been exhausted. Small country mines are also operated for a local supply.

The following record, taken along a ravine on the farm of E. B. Anderson, in Section 6, shows the structure and thickness of the Middle Kittanning coal:

		Ft.	In.
Shale, carbonaceous		--	3½
Coal, bony	*Middle Kittanning*	--	7
Coal, good		1	2
Shale		--	1½
Coal, good		1	7
Clay shale with sandstone layers		5	6

The middle bench of coal at this place is somewhat thin, but this is a local condition. A measurement taken under deep cover at the mine of the Pan-American Coal Co., located in Section 26, shows the thickness of the coal in this locality:

		Ft.	In.
Shale		11	--
Coal, bony	*Middle Kittanning*	--	8
Coal, good		1	7½
Shale		--	1½
Coal, good		1	9½
Clay, siliceous		2	--

The above measurements were practically duplicated at other mines in Section 26. In the vicinity of Cannelville the coal is close to drainage level. At the mine of George Helriggle, near this village, a sample was taken for chemical analysis. The measurements of the bed at this place follow:

		Ft.	In.
Shale		10	--
Coal, bony, excluded	*Middle Kittanning*	--	7
Coal, good		1	3
Shale		--	1
Coal, good		--	11
Smut with pyrite, excluded		--	1
Coal, good		--	10
Coal, bony, excluded		--	1
Clay		2	--

The overlying shale forms a good roof and extends over much of the Cannelville field. The upper bench of coal seldom contains fuel of value, as it is not only shaly, but pyritiferous. In sections 24 and 25 the bed has good thickness, as shown in the Turkey Run mine of the Pan-American Coal Co., where the coal measured 3 feet 4 inches with 5 inches of bone coal above. Along Baughman Run the Middle Kittanning coal is slightly thinner than it is in the Cannelville region, and it averages about 3 feet. Both the quality of the fuel and the conditions for mining are good. In the southeastern part of Section 16, on the S. and M. Irwin property, the marketable coal measures only 2 feet 10 inches, which thickness is retained in its extension eastward into Section 17.

On the farm of J. L. French, in the western part of Section 15, the coal was well exposed for measurement, and the following record secured:

		Ft.	In.
Sandstone and shale		20	--
Coal, bony	*Middle Kittanning*	--	7
Coal, good		1	8
Shale		--	1
Coal, good		1	5
Clay and covered		5	--

In a small mine on the same property, but in the southern part of Section 15, the good coal is 2 feet 9 inches in thickness. The roof here is 8 inches of bone coal, 2 feet of shale, and then a massive, shaly sandstone.

East of Brush Creek, in Section 14, the coal is somewhat thin, but of good quality. Several small mines are operated to supply the farmers in this locality. The measurements given below, and taken in a mine on the L. E. Showers farm, are representative of the thickness of coal in the area:

		Ft.	In.
Shale		15	--
Shale, dark, with coal bands		--	6
Coal	*Middle Kittanning*	1	6
Shale		--	1
Coal		1	3
Clay, siliceous		1	--

In this region the overlying shales form an excellent roof so that a good yield of coal is possible in mining. The coal benches are rather free from pyrite or shale. The coal in Section 6 has the thickness given below. The measurement was made on the property of C. K. Sanders.

		Ft.	In.
Shale and sandstone		30	--
Coal, bony, with shale	*Middle Kittanning*	--	10
Coal, good		1	6
Shale		--	1½
Coal, good		1	4
Clay, sandstone, and covered		30	--

The measurement of the bed in Section 7 is practically the same. The coal is above drainage along the Muskingum River in the northern part of Brush Creek Township, and is largely mined both for local use and for shipment. Near Sealover, in the northern part of Section 13, on the property of Victoria Tyler, the bed thins to 2 feet 5 inches of good coal. South of this the coal is again exposed in the bed of a stream and the middle bench measures 1 foot 5 inches and the lower bench 1 foot 3 inches. It was formerly mined in a large way in this locality for railroad shipment. The interval from the base of the Middle Kittanning to that of the Upper Freeport bed, which was also formerly worked, is about 88 feet. In the northern part of Section 12, a small shipping mine is operated by the Clay Nutter heirs. The bed here has the following thickness and structure:

		Ft.	In.
Shale		10	--
Coal, bony	*Middle Kittanning*	--	2
Coal, good		1	5
Shale		--	1
Coal, good		1	3
Clay, siliceous		3	--

In Brush Creek Township, the Middle Kittanning coal is thickest in the Cannelville field and thins in its extension northward along Brush Creek and the Muskingum River. The upper bench of coal is everywhere of poor quality and on oxidizing soon loosens and falls. The prevailing rock above this is shale, which forms an excellent roof. The average thickness of the good coal is about 3 feet, and the unworked area is large.

Harrison Township.—The area above drainage of the Middle Kittanning coal in Harrison Township is small, being confined to the valley of the Muskingum River from the western line to opposite the mouth of Salt Creek, where coal was formerly obtained in the bed of the stream. Coal is reported by drilling tests in the remainder of the township, but no accurate records of the thickness were obtained. Considering the remarkable persistency of the coal in this county, its extension under all of Harrison Township is to be expected. Along the stream courses it is within easy shafting distance, 100 feet or less, as the Upper Freeport coal is above drainage as far south as Stone, in Section 30. In the northern part of the area where the bed is above cover, the coal is somewhat thin, but along Brush Creek, in Brush Creek Township, the coal on the average thickens in its extension southward, which may also be the case in Harrison Township. Operations, however, should be based only on actual tests by the drill.

The following record was secured at a small wagon mine, located west of Sycamore Hollow, on the property of Mrs. Frank Stevens:

		Ft.	In.
Shale		3	--
Coal, good	*Middle Kittanning*	1	4
Shale		--	1
Coal, good		1	4
Clay, siliceous		2	--

Another section taken about one-half mile up Sycamore Hollow, but on the same property, is practically a duplicate of the above. Near Philo the coal as an average is slightly greater in thickness than it is in the localities named above. A record taken in a mine just north of the village follows:

		Ft.	In.
Shale with some bone coal		1	6
Coal, good	*Middle Kittanning*	1	5
Shale		--	2
Coal, good		1	4
Clay, siliceous		2	--

Although the bed is somewhat thin in northern Harrison Township, the fuel is of good quality and is well liked for general domestic purposes. The roof shale is solid and strong except where the massive overlying sandstone replaces all but a foot or so, under which conditions percolating waters loosen the shale so that it is somewhat dangerous to the workmen. In new workings, however, but little trouble is occasioned from this source.

Wayne Township.—A good part of the domestic fuel as well as that used for factory purposes in Zanesville has been drawn for years from the Middle Kittanning coal of Wayne Township. Many small wagon mines are found over the western part of the area, but at present no railroad mines are operated. Although the quantity of coal that has been taken from the township is large, the supply yet available will last for many years, as but little of the field is exhausted. The bed is above drainage along the Muskingum Valley from Zanesville to the mouth of Salt Creek, where it passes below cover.

In the vicinity of Duncan Falls the Middle Kittanning coal is generally about 2 feet 6 inches in thickness. The bed here is close to drainage level and but little worked. West of this the bed thickens somewhat as is shown by the following record taken in the mine of Frank J. Paul, in Section 4:

		Ft.	In.
Shale		8	--
Coal, bony, with shale	*Middle Kittanning*	--	8
Coal, good		1	9
Shale		--	1½
Coal, good		1	3
Clay, siliceous		2	--

In this mine a sample was taken for chemical analysis. Other wagon mines in which the bed has about the same average thickness as shown above were operated by A. S. Shipps, Peter Paul, Jacob Varner, and F. H. Fisher. In Section 14, on the land of Joseph Ellerman, the bed has the following measurement:

		Ft.	In.
Shale, gray		6	--
Coal and shale	*Middle Kittanning*	--	8
Coal, bony		--	2
Coal, good		1	8
Shale		--	1
Coal, good		1	2
Clay, siliceous		1	--

East of this in Section 15, the coal thickens slightly and has been mined for many years on the F. H. Fisher property, where 2 feet 11 inches of marketable coal was found. At the mine of Arthur Hoff, at the head of Howards Lane Hollow, the lower bench of coal measures 11 inches, the middle bench 1 foot 10 inches, and the upper layer of

bony coal 10 inches. The roof of the coal is a tough gray shale. Small mines are operated on the Lewis Fisher property, in Section 7. Dogs were used for the motive power in hauling the coal from the mine in 1917. This practice was also observed at other mines in Wayne Township. The supply of coal in Salt Gum Hollow is nearing exhaustion as the bed has been mined for many years. The thickness at this place is 2 feet 10 inches of marketable coal.

The area just east of Zanesville has been extensively mined also, but some fuel is yet available. The structure of the bed is shown in the following record taken at the No. 2 plant of the Burton-Townsend Brick Co., where the coal is utilized for fuel and the overlying shale for the manufacture of paving block:

		Ft.	In.
Shale		40	--
Coal, bony	*Middle Kittanning*	--	7
Coal, good		2	2
Shale		--	1
Coal, good		--	10
Clay, plastic, shaly		5	6

No drill records were obtained showing the thickness of the Middle Kittanning coal under cover in eastern Wayne Township, but from the conditions of the bed along its outcrop the area should be productive. The coal is all within easy reach by shafting.

Springfield Township.—The area of Middle Kittanning coal in Springfield Township is small, being about 2½ square miles. The bed extends across the entire area, but lies near the summits of the high ridges and knobs. In a part of the field the covering is so shallow that the coal is rotten and therefore of no value, or the roof shales are so weathered that drift mining is dangerous. Small areas, however, are found in which the roof has such strength that the coal is regularly mined for a part of the neighborhood supply. The average thickness of the bed shown by outcrop and mine measurements is about 3 feet. Coal is present in nearly every section of the township.

The Middle Kittanning coal was formerly mined on the property of W. G. Rehl, in Section 2. The thickness reported was 2 feet 6 inches. In the western part of Section 10, on the farm of Frank G. Grether, the following record was secured in a small mine:

		Ft.	In.
Shale and covered		80	--
Coal, bony	*Middle Kittanning*	1	--
Coal, good		2	--
Shale		--	1
Coal		--	8
Clay, siliceous		3	--

Other small mines have been operated in this vicinity and from reports the coal is not yet exhausted. In the northwestern part of Section 15 a measurement shows 3 feet of marketable fuel on the farm

of Joseph Russell. Small areas of unworked coal are present also along the ridges in the southern part of the township. Further, considerable fuel will be obtained by stripping when the coal with sufficient covering for drift mining is exhausted.

Hopewell Township.—The largest area of Middle Kittanning coal in Hopewell Township is found on the main ridge near Mt. Sterling and Coaldale. Small patches of fuel are also present on the ridges extending northward from Mt. Sterling and southward from Coaldale. The total area is about 1 square mile. The covering is generally shallow and the coal badly weathered. Small mines were formerly operated for local fuel at Mt. Sterling, where the deposit is reported to be more than 3 feet in thickness. The quantity of fuel yet available by drift mining is small.

Falls Township.—The Middle Kittanning coal in Falls Township is present in small areas on the main ridge north of Zanesville, and on high knobs of the ridge south of the Licking River. The small field north of Zanesville has been largely exhausted. The coal is reported to be about 3 feet in thickness and to be of good quality. No mines were in operation when the region was visited in 1916.

Muskingum Township.—In Muskingum Township the Middle Kittanning coal is present along the main ridge that extends from Rock Cut westward and southward to Stringtown. A few small patches also occur on the high knobs in the northeastern part of the township. The total area of coal is approximately $1\frac{1}{2}$ square miles. The main body of the coal with sufficient covering for drift mining is exhausted. On the farm of Dennis Mattingly, located on the ridge at the head of Blount Run, 3 feet 5 inches of marketable coal was found, but near the Sandy Ridge School, on the property of Ernest Ferrell, the bed thins to 2 feet 8 inches. The lower bench of coal is absent and the upper bony stratum is poorly represented. The middle bench has exceptional thickness and the fuel is of good quality.

Washington Township.—The Middle Kittanning coal in Washington Township is above drainage along the Muskingum River and well towards the headwaters of its small tributaries. The total area of coal in the township is about 20 square miles, of which only a small territory in the vicinity of Zanesville has been exhausted. The general thickness of the bed on Mill Run is shown by the following section, taken in a small mine:

		Ft.	In.
Shale		8	--
Coal	*Middle Kittanning*	2	4
Clay	*Middle Kittanning*	--	1
Coal	*Middle Kittanning*	--	5
Clay, siliceous		2	--

Several small mines were formerly operated near Wortley, where the average thickness of the bed is slightly less than 3 feet. In the

northeastern part of Section 13 the member has the following structure and thickness on the William H. Bolin farm:

		Ft.	In.
Shale, gray		2	--
Shale, carbonaceous		--	2
Coal, bony	*Middle Kittanning*	--	1
Shale, carbonaceous		--	2
Coal, bony		--	2
Coal, good		1	11
Clay		--	1
Coal, good		--	10
Clay, plastic		2	--

South of this, at the mines of the Coaldale Coal Mining Co., the structure is the same, except that the middle bench of coal expands to 2 feet 2 inches. About one-half mile south of the Hague School the bed is well exposed along the road. The lower bench at this place is only 3 inches in thickness, but the upper bench measures 2 feet 1 inch. At the mine of John Mahoney, which faces the Muskingum River, the coal has the following thickness:

		Ft.	In.
Shale		12	--
Coal, bony, with carbonaceous shale	*Middle Kittanning*	--	4
Coal, good		2	--
Shale		--	1
Coal, good		1	1

Just north of the Hague School, on the W. H. Bowers property, the lower bench of coal measures 8 inches and the middle bench 2 feet 3 inches. At this place the interval to the Lower Kittanning coal, which is 1 foot 8 inches in thickness, is 24 feet, and that to the Upper Freeport coal, which is only 4 inches in thickness, is 68 feet. In the northern part of Section 3 a small mine is opened on the land of Jesse Mears. The measurements of the coal are given below:

		Ft.	In.
Coal, good	*Middle Kittanning*	2	2
Clay		--	1
Coal, good		--	9
Clay, siliceous		1	--

The roof shales at this place are very fossiliferous and afford good collecting. They appear to take the place of the upper or impure bench of the coal and are dark and somewhat carbonaceous in character. The fossils in most part are of pyrite. *Chonetes* and *Productus* are the most common genera. Near the head of Blount Run, on the property of Levi Bunting, the following measurements were secured in a small mine:

	Ft.	In.
Shale, dark, very fossiliferous	--	7
Shale, soft	--	2

		Ft.	In.
Coal, good		2	--
Clay shale	*Middle Kittanning*	--	1
Coal, good		--	5
Clay, siliceous		1	--

On the northern tributary of Blount Run, on the property of A. Lewis, coal is mined for local use, and 3 feet of marketable fuel is present. The thickness of the bed is practically the same north of this at the mine of Arthur Stotts. Along the small stream in the northern part of the township coal is mined both by drifting and by stripping. A record obtained on the land of J. W. Jackson follows:

		Ft.	In.
Shale, dark, very fossiliferous		--	10
Shale, dark, with thin coal bands		--	6
Coal		2	4
Clay	*Middle Kittanning*	--	2
Coal		--	10
Clay, siliceous		1	--

From all the measurements made of the Middle Kittanning coal in Washington Township, the average thickness of the lower bench is 8 inches, of the parting 1 inch, and of the middle bench 2 feet 2 inches. The conditions for mining are everywhere good as the roof is a tough shale and the floor a siliceous clay. Although many small mines are in operation, but little of the area is exhausted except on Mill Run, near Wortley, and along the river hills north of this to Gilbert.

Cass Township.—A few small areas of Middle Kittanning coal are present along the main ridges in the eastern part of Cass Township. The deposits have been worked for many years, but small quantities of fuel are yet available by drift mining and more may be recovered by stripping. The measurements given below were taken in a small mine on the farm of J. Schumaker, which is located about 1½ miles southwest of Dresden:

		Ft.	In.
Coal, bony		--	10
Shale		--	1
Coal, good	*Middle Kittanning*	2	8
Clay		--	1
Coal		--	3
Clay, siliceous		3	--

The total thickness of good coal in part of the area is reported to be 3 feet, the increased thickness being due to an expansion of the lower bench.

Madison Township.—In Madison Township the Middle Kittanning coal lies near the summits of the ridges in the western part, but close to drainage level in the eastern part. The total area of coal is about 15 square miles and but little of this has been exhausted by mining. The average thickness of marketable coal from a number of measurements is about 3 feet 1 inch. The bed is very steady through-

out the area and the fuel of standard quality. West of Adamsville 2 miles, on the property of Joseph Smith, the following measurements were taken in a drift mine:

		Ft.	In.
Shale		3	--
Coal, bony, with shale bands	*Middle Kittanning*	1	--
Coal, good		2	4
Clay		--	2
Coal, good		--	8
Clay, siliceous		2	--

The measurement of the coal in this locality is reported to vary from 3 feet to as much as 4 feet 6 inches. The roof is a tough shale that causes but little trouble in mining. In the southeastern corner of the township 3 feet of marketable coal was measured in the mine of T. D. King. The thickness of the bed is much the same in the mines of Charles Edwards and A. C. Sturtz, which are located on South Branch near the eastern line of the township. At the mine of John McNeish, south of the Fritz School, the following record was obtained:

		Ft.	In.
Shale, very fossiliferous		1	--
Coal	*Middle Kittanning*	2	4½
Shale		--	1½
Coal		--	11
Clay, very hard		2	--

The coal in this area is reported by Mr. McNeish to vary from 3 feet 3 inches to 3 feet 9 inches in thickness. The roof shales in this mine are very fossiliferous. As noted in several sections, these shales are rather persistent over northern Washington and southern Madison townships. Along Symmes Creek, north of the Fritz School, the coal thins somewhat and measures 2 feet 5 inches on the farm of Harmon T. Ridgway in Section 21. In this locality the coal is reported to vary from 2 feet 4 inches to 3 feet in thickness. On the land of George Lane, south of the crossroads on Symmes Creek, the structure of the coal in a mine follows:

		Ft.	In.
Shale, dark, with thin layers of coal		1	--
Coal	*Middle Kittanning*	2	5
Clay		--	1
Coal		--	6½
Clay, plastic		2	--

On the farm of E. R. Birkhimer, in Section 19, a small drift mine was being operated for a local supply. The structure of the bed at this place is as follows:

		Ft.	In.
Shale, with bone coal		--	7
Coal, good	*Middle Kittanning*	2	6
Clay shale		--	2
Coal, good		--	11
Clay, siliceous		2	--

The miners stated that on North Branch the thickness of the coal varies from 3 feet to 3 feet 6 inches. Along the upper course of this stream the bed has been mined in but few places and there only in a very small way.

The village of Dresden has drawn its main supply of fuel for many years from the Middle Kittanning coal of western Madison Township. The bed at this place lies well up on the ridges so that the areas of coal are not large. The general thickness of the bed is shown by the following section taken at the mine of E. R. Birkhimer, which is located about 2 miles east of Dresden:

		Ft.	In.
Shale		10	--
Coal, bony, with shale	*Middle Kittanning*	--	6
Coal, good		2	7
Shale		--	1
Coal		--	8
Clay, siliceous		2	--

Along the ridge east of this, wagon mines are operated on the farm of John F. Egbert and on that of Grant Little. The thickness of the marketable coal averages about 3 feet 2 inches. In Section 13, on the land of Milton Griffin, the coal measures 2 feet 11 inches. The Upper Freeport coal is present in this locality and lies 80 feet above the Middle Kittanning coal.

On the ridge about 2 miles south of Adams Mills fuel for local needs has been mined for many years. Measurements taken in the mine of Arthur McBurney follow:

		Ft.	In.
Shale		4	--
Shale with coal bands	*MiddleKittanning*	--	6
Coal, good		2	9
Clay shale		--	1
Coal		--	8
Clay, plastic		1	--

Near the Ross School, in the northeastern part of the township, the coal is mined in a small way for local needs. In a mine on the property of James Scott the bed where sampled for chemical analysis has the thickness given below:

		Ft.	In.
Shale, good roof		2	--
Shale, with bony coal	*Middle Kittanning*	--	6
Coal, good		2	4
Shale		--	1½
Coal, good		--	8
Clay, siliceous		3	--

At a mine on the lands of C. and S. Tilton the marketable coal measures 3 feet 3 inches. Along the Muskingum River east of the Ross School the coal is very persistent, but no good exposures for measurements were observed.

Adams Township.—The Middle Kittanning coal is above drainage for a short distance along North Branch in the western part of Adams Township and along Wills Creek in the northern part. Judging from the general continuity of the bed and from the outcrop conditions in Madison and Monroe townships, the total area in which coal is reasonably certain is nearly 24 square miles. One measurement which is given below was secured on North Branch in a small mine on the land of John Aler:

		Ft.	In.
Sandstone, massive		10	--
Coal, good	*Middle Kittanning*	2	2½
Clay shale	*Middle Kittanning*	--	1
Coal, good	*Middle Kittanning*	--	8
Clay, siliceous, light		2	--

In this region the roof of the coal is a massive sandstone which extends northward across the area to Wills Creek. In the northern part of Section 3, C. H. Wilcox operates wagon mines to supply the rural demands. In one of these the coal was sampled for chemical analysis and has the following general structure and thickness:

		Ft.	In.
Shale		3	--
Coal, bony, rejected	*Middle Kittanning*	--	4
Shale	*Middle Kittanning*	--	2
Coal, good	*Middle Kittanning*	1	11
Pyrite, irregular	*Middle Kittanning*	--	1
Coal, good	*Middle Kittanning*	--	7½
Clay shale	*Middle Kittanning*	--	1½
Coal, good	*Middle Kittanning*	1	5
Clay, plastic, siliceous		2	--

Mr. Wilcox states that the bed holds its thickness well in this locality, and that the roof gives but little trouble in mining. On Big Run, 1½ miles from its mouth, on the property of G. C. Gress, 3 feet 11 inches of marketable coal was found. On the east branch of Big Run the bed has been worked in a small way, and the coal is reported to be about 4 feet in thickness.

Salem Township.—In Salem Township the Middle Kittanning coal is present above drainage for about 1 mile along Symmes Creek, and along South Branch west of Adamsville. In both of these places the coal is reported to measure more than 3 feet. Owing to the fact that the bed is thick and persistent in Washington and Madison townships to the west, and in Monroe Township to the northeast, as well as in Adams Township to the north, the general trend of the productive field should include all of Salem Township. The presence of the coal at this place is also indicated by oil well records, but no definite measurements were obtained. Along the valleys the coal is within easy shafting distance, the horizon along most of the water courses being less than 100 feet below the surface.

Monroe Township.—The area of Middle Kittanning coal in Monroe Township is about 22 square miles, and from outcrop indications the bed is not only persistent, but has excellent thickness in the entire field. No wants were observed. The thickness of good coal from all the measurements obtained is about 3 feet 8 inches. The bed is above drainage along White Eyes Creek and its tributaries, from the county line to south of Otsego. It is also above cover along Wills Creek in the vicinity of Marquand Mill. This coal has been mined for many years for local consumption, but the area exhausted is small. The field is of exceptional value and is favorably situated for mining on a large scale. Near Otsego, in Section 13, the marketable coal measures 3 feet 4 inches. The most southern exposure of coal in the central part of the township is at the mine of Burt Larson, which is located about 1 mile due south of Otsego. The record obtained follows:

		Ft.	In.
Shale, tough		10	--
Coal, bony	*Middle Kittanning*	--	6
Coal, good		2	5
Shale		--	1
Coal, good		--	10

This coal was formerly mined on the land of T. L. Sprague, in the southeastern part of Section 7. The thickness of the bed was stated by Mr. Sprague to be about 4 feet in local areas. In the western part of Section 8 a sample was taken for chemical analysis in the mine of George Buker. The measurements obtained are given below:

		Ft.	In.
Shale		4	--
Coal, bony, excluded	*Middle Kittanning*	--	1
Shale with pyrite		--	2
Coal, bony, excluded		--	3
Coal, good		2	7
Shale		--	1½
Coal, good		--	10
Clay, siliceous		2	--

Mines are also operated on the lands of Frank Workman in this vicinity. The coal has about the same general thickness and is of good quality. In the eastern part of Section 8 a small mine operated on the property of Albert Bainter shows 3 feet 6 inches of marketable coal. The coal is stated to thicken to the north in this locality. In a mine in the central part of Section 8, on the land of T. C. Riney, the good coal measures 3 feet 10 inches in thickness, and the impure roof coal 4 inches. On the property of Hamlin Lawrence, in Section 12, the following record was obtained:

		Ft.	In.
Shale, with bone coal		4	--
Coal, good	*Middle Kittanning*	2	10
Shale		--	2
Coal		1	--
Clay, siliceous		2	--

The coal is reported to be very steady in thickness in this locality as well as in Section 11. At a country mine in the southern part of Section 10, on the farm of William B. Snell, 3 feet 4 inches of marketable coal was found.

In the northern part of Section 10 the thickness of the coal is somewhat greater, as shown by the following measurements obtained in a mine on the farm of Leonard Eckelberry:

		Ft.	In.
Shale		15	--
Coal, bony	*Middle Kittanning*	--	6
Coal, good		3	2
Clay shale		--	2
Coal, good		--	6
Clay, siliceous		2	--

East of White Eyes Creek in Section 1 the coal was sampled for chemical analysis in a mine on the farm of W. B. Eltringham. The structure of the bed is shown in the following record:

		Ft.	In.
Shale		10	--
Coal, bony, excluded	*Middle Kittanning*	--	6
Coal, good		2	9
Shale		--	1
Coal, good		--	8
Clay, plastic, siliceous		2	--

West of White Eyes Creek the coal has excellent thickness in local areas, as shown by the following record taken in a mine on the farm of Grover Sprague in the northwestern part of Section 1:

		Ft.	In.
Shale		2	--
Coal, bony	*Middle Kittanning*	--	6
Coal, good		3	--
Clay shale		--	2
Coal, good		1	6
Clay, siliceous, plastic		3	--

The bed in sections 2, 3, and 4 is reported to vary from 3 feet 6 inches to 4 feet 6 inches in thickness. No good exposures were found when the region was visited in 1916. This coal was formerly mined at Marquand or Johnson Mill, in Section 5, for the salt works and for local use. The structure and thickness of the bed here are as follows:[1]

		Ft.	In.
Shale, black		--	4
Coal	*Middle Kittanning*	--	6½
Shale, coaly		--	½
Coal		--	11
Shale, coaly		--	1
Coal		1	2
Clay		--	1
Coal		1	--
Clay		3	--

[1]Geol. Survey Ohio, Vol. III, p. 255.

The Middle Kittanning coal in the Monroe Township field is thus seen to have excellent thickness and continuity. The roof shale and impure coal have good strength for regular drift mining, and the underlying clay is sufficiently solid to support the weight of the overburden on the stumps and pillars. The coal is of standard quality and is solid and bright. The parting is clay-like and may be removed by cutting. The field is so situated that all the coal is easily available by short switches leading along the valleys. It is easily the most valuable undeveloped coal area at or close to drainage in Muskingum County.

Economic Value of the Middle Kittanning Coal

The Middle Kittanning coal is and will remain the great source of fuel upon which the industrial wealth of Muskingum County so largely depends. It is also by far the most important source of domestic fuel, in fact it contributes more coal for domestic needs than all the other beds combined. As previously stated, the known and reasonably certain area of undeveloped coal is about 150 square miles. The mean thickness of the bed, from more than 100 measurements taken in this county, and well distributed along the entire outcrop, is as follows:

		Ft.	In.
Shale, good roof		12	--
Coal, bony, roof coal	*Middle Kittanning*	--	7
Coal, good		2	--
Shale		--	1½
Coal, good		1	1
Clay, siliceous, plastic, light		4	--

This gives an average thickness of 3 feet 1 inch for the marketable coal. Considering the average only 3 feet, as the bed is somewhat more frequently mined in the thicker coal, the total yield per acre is approximately 5,400 tons of 2,000 pounds each. Counting 70 per cent available by drift mining, the quantity obtainable is 3,780 tons per acre or 2,419,200 tons per square mile. The 150 square miles of undeveloped territory will thus yield 362,880,000 tons. At the present rate of consumption the supply is sufficient to meet the demands in this county for many generations.

The general conditions for drift mining are very good. The coal of value is directly overlain by a stratum of bone coal varying from a few inches to more than 1 foot in thickness. This contains considerable pyrite which on oxidation tends to loosen the mass so that it eventually falls. Under ordinary conditions, however, this action is so slow that but little trouble is experienced in regularly worked mines. The unaffected material is solid and strong and forms a safe roof. This bone coal is not removed except along haulage ways where additional height is required. The prevailing rock above this coal stratum is shale which has good thickness and strength. In a few

localities it is partially or completely replaced by a massive sandstone which there forms the roof of the coal. Where the shale between the coal and sandstone is thin, percolating waters often become so effective that the shale loosens and falls. These conditions, however, are local and in new workings not especially troublesome. On the whole the roof of the Middle Kittanning coal in Muskingum County is such that with systematic mining a high yield of fuel is possible and reasonable safety to the workmen is assured.

The floor of the coal is everywhere a siliceous, plastic clay. Its strength is such that no large pillars and stumps need be left to support the weight of the overburden. It makes good footings for posts, except in especially wet mines where cross sills are required. The floor of the coal is usually very regular, not given to sudden dips and rises, and thus allows free drainage. The general dip of the rocks in most of the county is about 23 degrees south of east, hence where possible the main entryways should be run 23 degrees west of north, which allows free drainage and downhill haulage for the loaded cars.

The bed is very steady in thickness and structure across the entire county. It varies in thickness somewhat from place to place, but the changes occur gradually, under which conditions unprofitable mining or additional expense owing to wants or thin places in the coal is largely eliminated. The constancy of structure is also a favorable factor, for it allows a fixed type of mining machinery to be used. The parting between the two benches of good coal is seldom less than 1 inch or more than 2 inches in thickness and, as the lower coal bench is very steady over an area usually covered by even a large mine, this parting lies at approximately a constant distance above the floor of the coal. The cutting should always be done along this parting, thus eliminating refuse, saving coal, and keeping the product clean. The parting which averages about $1\frac{1}{2}$ inches in thickness will yield about 425 tons per acre to be removed from the mine or thrown back in old workings.

Most of the mines, especially the smaller ones, are operated in a haphazard way with but little attention to conservation of fuel or to future operations. A few of the larger mines are operated in a systematic way. The Hydraulic Press Brick Co. is mining in an area worked about 30 years ago. The average daily capacity of the mines is nearly 30 tons of fuel which is used in the manufacture and burning of ceramic products. The mines are located in Section 34, Newton Township. The Monitor mine of the Burton-Townsend Brick Co. has an output of about 400 tons per day. The coal is cut by machinery and is hauled by electric motors. The area controlled includes about 2,600 acres and lies in sections 13, 14, 23 and 24, Newton Township, and in sections 14, 15, 16, and 17, Brush Creek Township. A part of the fuel is used for ceramic purposes at their plants near Zanesville,

and the remainder sold in the general markets. The mines of the Pan-American Coal Co. are in the vicinity of Cannelville in the southern part of Brush Creek Township. They are machine operations with a daily capacity of 500 tons. The fuel is shipped for factory and domestic purposes. A small mine is operated by the Clay Nutter heirs in Section 12, Brush Creek Township. The coal is cut by machinery and hauled by mule power. The capacity is 50 tons per day. More than 100 small mines distributed throughout the field are worked for the local domestic and factory trade. In these the coal is either cut by the pick or shot off the solid and hauled to the tipple by mule, dog, or man power.

The general quality of the Middle Kittanning coal in Muskingum County is shown by the following analyses. The samples were taken according to specifications of the Federal Geological Survey or Bureau of Mines.

The Middle Kittanning coal was sampled in the mine of George Helriggle, which is located just east of Cannelville, by R. E. Lamborn and the writer in 1917. The sample was taken well under cover where the coal was bright and solid and where the mine was dry. The analysis given below was made by Prof. D. J. Demorest:

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	68.35	Moisture	5.65
Hydrogen	5.64	Volatile matter	44.36
Oxygen	13.42	Fixed carbon	42.85
Nitrogen	1.02	Ash	7.14
Sulphur	4.43		
Ash	7.14		

Calorific value { 6,960 calories. 12,564 B. t. u.

Air drying loss of moisture, 2.1 per cent.

Fusion of ash, { incipient, 1,109° C. complete, 1,160° C.

S. T. Jones mine (now the Monitor mine of the Burton-Townsend Co.), Section 14, Newton Township, Muskingum County. Sample 18 by 5 inches, cut by B. A. Eisenlohr in July, 1907.[1]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	65.88	Moisture	5.02
Hydrogen	5.29	Volatile matter	38.16
Oxygen	12.18	Fixed carbon	47.26
Nitrogen	1.12	Ash	9.56
Sulphur	5.97		
Ash	9.56		

Calorific value { 6,758 calories. 12,164 B. t. u.

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 217.

A sample was cut by R. E. Lamborn and the writer in 1917 from the Middle Kittanning coal in the Frank J. Paul mine, which is located in Section 4, Wayne Township. The coal was bright and clean, but the mine was slightly wet. The analysis was made by Prof. D. J. Demorest:

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	67.21	Moisture	5.93
Hydrogen	5.67	Volatile matter	45.69
Oxygen	16.33	Fixed carbon	42.54
Nitrogen	1.24	Ash	5.84
Sulphur	3.71		
Ash	5.84		

Calorific value { 7,067 calories. 12,721 B. t. u.

Air drying loss of moisture, 1.9 per cent.

Mine of Frank Lacey, Washington Township, Muskingum County. Excellent sample cut from a section about 24 by 6 inches by B. A. Eisenlohr in July, 1907.[1]

Chemical Analysis and Calorific Value.

Ultimate		Proximate	
Carbon	67.16	Moisture	5.44
Hydrogen	5.34	Volatile matter	39.15
Oxygen	13.27	Fixed carbon	46.13
Nitrogen	1.18	Ash	9.28
Sulphur	3.77		
Ash	9.28		

Calorific value { 6,822 calories. 12,280 B. t. u.

Mine of Wesley Wells, Section 30 or 31, Harrison Township, Muskingum County. Excellent sample cut from section, 22 by 6 inches, by B. A. Eisenlohr in August, 1907.[2]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	67 71	Moisture	4.67
Hydrogen	5.38	Volatile matter	40.32
Oxygen	11.82	Fixed carbon	45.18
Nitrogen	1.16	Ash	9.83
Sulphur	4.10		
Ash	9.83		

Calorific value { 6,873 calories. 12,371 B. t. u.

Mine of Walnut Hill Coal Company, Section 13, Brush Creek

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 220.

[2]*Idem.*, pp. 220-221.

Township, Muskingum County. Excellent sample, about 13 by 7 inches, cut by B. A. Eisenlohr in August, 1907.[1]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	65.74	Moisture	5.08
Hydrogen	5.32	Volatile matter	39.75
Oxygen	12.49	Fixed carbon	45.40
Nitrogen	1.14	Ash	9.77
Sulphur	5.54		
Ash	9.77		

Calorific value { 6,802 calories. 12,244 B. t. u.

Mine of E. R. Birkhimer, Madison Township, Muskingum County. Excellent sample, about 24 by 5 inches, and cut by B. A. Eisenlohr in August, 1907.[2]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	66.69	Moisture	4.75
Hydrogen	5.35	Volatile matter	39.88
Oxygen	12.05	Fixed carbon	46.09
Nitrogen	1.28	Ash	9.28
Sulphur	5.35		
Ash	9.28		

Calorific value { 6,854 calories. 12,337 B. t. u.

Mine of E. U. Farrell, Madison Township, Muskingum County. Excellent sample, about 20 by 5 inches, and cut by B. A. Eisenlohr in August, 1907.[3]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	69.58	Moisture	4.62
Hydrogen	5.47	Volatile matter	40.95
Oxygen	12.58	Fixed carbon	47.85
Nitrogen	1.30	Ash	6.58
Sulphur	4.49		
Ash	6.58		

Calorific value { 7,126 calories. 12,827 B. t. u.

Near the Ross School, in the northeastern part of Madison Township, a sample for chemical analysis was taken by R. E. Lamborn and the writer in 1917, in a mine on the property of James Scott. The sample was taken well under cover where the coal was bright and solid. The mine was somewhat wet. The analysis was made by Prof. D. J. Demorest.

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 221.
[2]*Idem.*, pp. 221-222.
[3]*Idem.*, pp. 222-223.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	70.02	Moisture	6.13
Hydrogen	5.76	Volatile matter	44.25
Oxygen	14.16	Fixed carbon	44.42
Nitrogen	1.22	Ash	5.20
Sulphur	3.64		
Ash	5.20		

Calorific value { 7,108 calories. / 12,794 B. t. u.

Air drying loss of moisture, 2.2 per cent.

Mine of A. W. Smith, Muskingum Township, Muskingum County. The sample was cut from a section 18 by 5 inches, by B. A. Eisenlohr, in August, 1907. A little mud fell into the coal, hence the sample is not first class.[1]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	70.54	Moisture	5.55
Hydrogen	5.57	Volatile matter	40.27
Oxygen	13.77	Fixed carbon	48.95
Nitrogen	1.26	Ash	5.23
Sulphur	3.63		
Ash	5.23		

Calorific value { 7,191 calories. / 12,944 B. t. u.

The Middle Kittanning coal in the mine of C. H. Wilcox, located in Section 3, Adams Township, was sampled by R. E. Lamborn and the writer in July, 1917. The sample was cut in a new room where the coal was bright and solid. Although the mine was somewhat wet the coal was sampled in a dry place and is considered representative. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	71.41	Moisture	5.63
Hydrogen	5.69	Volatile matter	44.70
Oxygen	13 50	Fixed carbon	44.84
Nitrogen	1.25	Ash	4.83
Sulphur	3.32		
Ash	4.83		

Calorific value { 7,206 calories. / 12,971 B. t. u.

Air drying loss of moisture, 1.9 per cent.

Fusion temperature of ash { incipient, 1,101° C. / complete, 1,153° C.

About 1 mile north of Otsego in Monroe Township, this coal was

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 223.

sampled by R. E. Lamborn and the writer in 1917, in the mine of George Buker. The mine was slightly damp, but the coal was cut in a dry place. Sample was taken about 150 feet from the mouth of the entry. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	70.90	Moisture	5.52
Hydrogen	5.66	Volatile matter	44.73
Oxygen	14.20	Fixed carbon	45.12
Nitrogen	1.11	Ash	4.63
Sulphur	3.50		
Ash	4.63		

Calorific value { 7,241 calories. / 13,034 B. t. u.

Air drying loss of moisture, 1.9 per cent.

A sample of Middle Kittanning coal in the mine of W. B. Eltringham, located in Section 1, Monroe Township, was cut by R. E. Lamborn and the writer in July, 1917. The sample was taken about 150 feet from the mouth of the mine where the coal was bright and solid. The mine was damp, but the coal was cut in a fairly dry place. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	72.18	Moisture	5.88
Hydrogen	5.74	Volatile matter	43.81
Oxygen	14.03	Fixed carbon	46.51
Nitrogen	1.27	Ash	3.80
Sulphur	2.98		
Ash	3.80		

Calorific value { 7,308 calories. / 13,154 B. t. u.

Air drying loss of moisture, 1.9 per cent.

The Middle Kittanning coal has qualities which recommend it for general purposes. The average calorific value, 7,024 calories, is good for an Ohio coal, although the fixed carbon is low and the oxygen high. Owing to the large content of volatile matter the fuel burns with a rather long flame, but with the production of some soot. The sulphur which is combined principally with iron as pyrite averages about 4.35 per cent. This is detrimental for the burning of glazed ceramic products. The ash averages about 7 per cent and is somewhat troublesome from clinkering. It is usually of a chocolate or brownish-red color, owing to the influence of the iron oxides present. The cementing value of the coal is low, but it is the most pronounced in the coal from the lower bench.

The Middle Kittanning coal has a wide reputation for steam generation on account of its heating value and its free-burning char-

acter. The coal is also sufficiently strong and tough to withstand shipping and handling well; hence it is a satisfactory fuel for the Great Lakes trade. The coal is rated a fair domestic fuel as the sulphur and soot are somewhat troublesome and as the ash is moderately high. However, it does not fuse or coke, but burns freely until entirely consumed. The only objectionable factor of this fuel in the burning of ceramic products is the high content of sulphur. Unless care is taken the sulphur causes unsightly blisters on the glaze which thus excludes the products from the market. For burning such products as building brick, fireproofing, and paving block, this coal is well recommended. The coal is not in the coking class as the cementing value is low, the sulphur entirely too high, and the ash higher than the quantity usually demanded. The only way for its utilization in the manufacture of coke would be to crush and wash the fuel, mix it with some coal of a much better grade, as Pocahontas from West Virginia, and coke in a retort oven. At present such a procedure is not justifiable. As the natural gas resources become lower the Middle Kittanning coal will become more largely used in the manufacture of producer gas. The yield under distillation is about 3.80 cubic feet per pound of coal.

Economic Value of Middle Kittanning Clay

The Middle Kittanning clay lies directly below the Middle Kittanning coal and is very persistent in this county. The bed varies from 2 to 10 feet in thickness, but averages about 4 feet. The clay is of the usual plastic variety, but it is always siliceous and therefore somewhat low in bonding properties. Further, it is usually high in fluxes which impairs its refractory qualities. Tests seldom rate it above a third-grade refractory material. It is not considered a good stoneware clay on account of its lack of strength and its high fire shrinkage. This clay in conjunction with other clays and shales is used in a small way by the Hydraulic Press Brick Co. at Roseville, and by the Burton-Townsend Brick Co. at Zanesville.

SHALE ABOVE THE MIDDLE KITTANNING COAL

The prevailing rock in Muskingum County between the Middle Kittanning coal and the Lower Freeport limestone or coal is shale, the thickness of which varies from 20 to 50 feet. In many areas, however, the shale is more or less interstratified with shaly sandstone, but in places it is even replaced completely or in part by a massive coarse-grained sandstone. The shale is of the usual coal formation type and is variable in composition. This material is used extensively for the manufacture of paving block and building brick by the Burton-Townsend Brick Co., and the Harris Brick Co. located east of Zanesville, and to a small extent by the Hydraulic Press Brick Co. and the Roseville Paving Brick Co. located near Roseville.

The general stratigraphy of these shales is shown by the following section taken at the No. 1 plant of the Burton-Townsend Brick Co. east of Zanesville:

	Ft.	In.
Shale	5	6
Coal, bony, *Lower Freeport*	1	6
Shale, bluish-gray, in places the upper part very siliceous or interstratified with thin sandstone layers	26	--
Coal and partings, *Middle Kittanning*	2	6

At the No. 2 plant of this company, the shale is considerably thicker and is more uniform in composition. The bed is much the same also at the plant of the Harris Brick Co. At the plant of the Roseville Paving Brick Co., the rocks above the Middle Kittanning coal are shown in the record given below:

	Ft.	In.
Sandstone, massive, coarse-grained	5	--
Covered	3	8
Sandstone, thin-bedded, shaly	5	6
Shale, light	16	--
Coal, weathered, *Middle Kittanning*	3	3

These shales vary in color from light-gray through bluish-gray to dark shades, the latter coloration being due largely to carbonaceous matter. In composition they gradate from arenaceous shale on the one hand to shaly sandstone on the other. In a general way the plastic properties of the shale decrease as the silica increases. The general working properties of the material are usually excellent. It is reduced easily by the dry pan, and is converted readily to a plastic mud by the pug mill. The column formed by the brick machine is rather free from laminations unless the material is very plastic. Excess silica tends to cause cracks in the column. The green ware dries safely in almost any type of tunnel drier. Some trouble from scumming is occasioned here, however, if the circulation of air in the tunnels is sluggish. The ware vitrifies to a good dense body at temperatures between 1,800 and 1,900° F., as the total fluxes are usually between 10 and 12 per cent. Iron oxide is the chief component and usually makes up about one-half of the total. Potash is the flux next in importance and is followed by lime, magnesia, and soda. At maturity the body burned under oxidizing conditions has a cherry-red or brownish-red color and burned under reducing conditions it has a dark-brown or nearly black color. The paving blocks are up to the standard demanded by the trade and the building brick are well liked on account of quality and color.

LOWER FREEPORT SANDSTONE

The Lower Freeport sandstone is a conspicuous member in many places in Muskingum County, as it forms prominent escarpments with occasional cliffs along its line of outcrop. The position of the

member is between the Middle Kittanning coal and the Lower Freeport limestone or coal. In places it occupies nearly all of this interval, but in most localities the bed is thin, shaly, or even wanting. In some areas this sandstone so coalesces with the Upper Freeport sandstone that the line of separation is not evident, and there the total thickness of the beds varies from 50 to as much as 90 feet. The Lower Freeport sandstone is light-colored, loosely cemented, and medium fine-grained, and is generally cross-bedded. Where the deposit is thick it is often somewhat conglomeratic at the base. It is present in some state of development in Clay, Newton, Brush Creek, Harrison, Hopewell, Springfield, Wayne, Perry, Falls, Muskingum, Washington, Cass, Madison, Salem, Adams, Monroe, and Highland townships.

In the greater part of Clay and Newton townships the Lower Freeport member is represented either by a thick bed of rather coarse-grained sandstone, or by argillaceous layers interstratified with shale. The following section, taken at the quarry of the Hydraulic Press Brick Co., near Roseville, shows the Lower Freeport sandstone with good development:

		Ft.	In.
Sandstone, massive	*Lower Freeport*	28	--
Sandstone, shaly	*Lower Freeport*	1	6
Shale, light, siliceous		3	8
Shale, dark, carbonaceous		3	7
Coal and partings, *Middle Kittanning*		4	1

In local areas in these townships the Lower Freeport sandstone forms the roof of the Middle Kittanning coal. The member is usually massive and persistent along Brush Creek and its tributaries, and along the Muskingum River in Brush Creek Township. The cliffs and escarpments along the Muskingum River in the northern part of Harrison Township are due to the massive development of this sandstone, which at this place is 20 to 50 feet in thickness. It is separated from the underlying Middle Kittanning coal by shale, varying from 1 to 10 feet.

The Lower Freeport sandstone is regularly present along the ridges that are of sufficient height to carry the bed in Springfield, Falls, Hopewell, and Muskingum townships. Many of the sand beds along the ridge roads are due to the disintegration of this rock. In parts of Washington Township the member is from 20 to 40 feet in thickness, and in places it coalesces with the overlying Upper Freeport sandstone, also massively developed. The round knobs so conspicuous on the ridges west of Dresden, in Cass Township, are due to the influence of the Lower Freeport sandstone, which at this place is massive in character, rather coarse-grained, and somewhat pebbly at the base.

The Lower Freeport sandstone in some state of development is

present in most of Madison Township, and it extends eastward into the western part of Salem Township, where it passes below drainage. In places it lies on or within a few feet of the Middle Kittanning coal. Further, in local areas, this member unites with the Upper Freeport sandstone, so that the total thickness of such rocks varies from 50 to 90 feet. The member is above drainage along Wills Creek in the northern part of Adams Township, and for short distances along the headwaters of Symmes Creek in the western part. It is rather persistent, and in local areas massively developed, under which condition it is coarse-grained and usually pebbly at the base. The outcrop of this member, as well as that of the overlying Upper Freeport sandstone, is very noticeable by the steep slopes of the hills along Wills Creek and along White Eyes Creek to Otsego in Monroe Township.

The Lower Freeport is a loosely-cemented sandstone, except where it is somewhat shaly in character, and is seldom sufficiently weather resistant to form cliffs along its outcrop. Clay is the chief cementing material, but iron oxides, lime, and magnesia are also present. The rock is decidedly micaceous. The sand grains are well rounded. The Lower Freeport sandstone has been but little utilized in Muskingum County. On account of the rapid disintegration, where exposed to weathering agencies, the material is of no value for building. If ground with more argillaceous weathered material it will make a molding sand suitable for rough work. It is too impure for low-grade glassware, and even washing will not raise it to the standard demanded. A suggested use for the material in the massive coarse-grained deposit is for sand-blasting.

LOWER FREEPORT LIMESTONE

The Lower Freeport, or as it is sometimes called Norris, limestone, although very unsteady in Muskingum County, is sufficiently well represented to be considered a stratigraphic unit in the geological section. The horizon is marked by a bed of limestone in local areas in Harrison, Brush Creek, Perry, and Washington townships, and by small nodules of limestone in clay at a few other places in the county. Occasionally along the outcrop the limestone has been so altered by weathering that it has been converted to an impure limonite ore. Even where best developed the limestone is of a blocky or nodular structure, and both the upper and lower surfaces of the bed are very irregular. In places it consists of nodules of limestone irregularly bedded in clay or clay shale. The color varies from a light-gray in the relatively pure limestone to yellow or brown in the impure rock. The limestone lies 3 to 10 feet below the Lower Freeport coal, or 40 to 45 feet above the base of the Middle Kittanning coal.

The following record, taken along Duncan Run, in Section 21, Harrison Township, illustrates the general stratigraphy of the Lower Freeport limestone:

		Ft.	In.
Coal, good		--	2
Coal, bony	*Lower Freeport*	--	4
Coal, good		--	6
Clay shale		4	--
Limestone, nodular, *Lower Freeport*		1	--

At this place the thickness of the bed varies from 6 inches to 1 foot 8 inches. The stone is of a light-gray color and is non-fossiliferous. About one-fourth mile north of Sonora, in Perry Township, the member is a well-defined bed of limestone about 1 foot in thickness. Small nodules of limestone, often ferruginous, were also noticed in a few places in Madison and Monroe townships.

The economic value of the Lower Freeport limestone is trifling as the volume and extent of the deposits are small. In a few places small quantities of the material may be obtained easily along stream beds or along hillsides. The gray limestone in the thicker deposits is of such quality that it may be used for agricultural purposes or for road building.

LOWER FREEPORT OR NO. 6a COAL AND CLAY

The Lower Freeport coal, which has good thickness in eastern Ohio where it is called the Steubenville shaft coal and in southern Ohio where it is known as the Hatcher bed, is usually very thin and inconspicuous in Muskingum County. Moreover, in parts of this area the place of the coal is taken by sandstones. On the average this member lies about 48 feet above the Middle Kittanning coal and about 44 feet below the Upper Freeport. The interval from the Lower Freeport coal to the underlying Lower Freeport limestone, which is present only in small areas, is nearly 6 feet. The average thickness of this coal is not more than 6 inches and the maximum thickness observed is 3 feet 3 inches. The area of most importance is found in southern Madison Township. The clay associated with this coal is more persistent than the coal and varies from 1 foot to as much as 6 feet in thickness. It is everywhere of a siliceous character and of inferior quality. The Lower Freeport coal and clay are present in Clay, Newton, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Washington, Perry, Salem, Madison, Adams, Monroe, and Highland townships. In some of these townships, however, the areas of coal are so small or the members so poorly defined that they need not be considered.

The following record taken in Section 25, Brush Creek Township, shows the relation of the Lower Freeport coal to other well-known rocks:

	Ft.	In.
Coal, *Upper Freeport*	2	6
Clay and covered	11	--
Limestone, nodular, *Upper Freeport*	1	--
Covered	8	--
Clay and shales	29	3

	Ft.	In.
Coal, *Lower Freeport*	--	2
Clay, yellow to dark	3	6
Sandstone and covered	8	4
Clay shale	1	8
Sandstone, massive	11	8
Shale, light	15	--
Coal, weathered, *Middle Kittanning*	3	4

In no place in Clay, Newton, or Brush Creek townships was the Lower Freeport coal found to be more than 1 foot in thickness. Moreover the fuel is generally shaly and of no value. In Harrison Township the coal and its associated clay are above drainage in the northern part of the area. Along Duncan Run, in Section 21, the coal is 8 inches thick and is occasionally stripped for local use. The interval from this member to the Upper Freeport coal in this locality is from 45 to 50 feet. At the No. 1 plant of the Burton-Townsend Brick Co., a small pocket of impure coal marks the Lower Freeport horizon. The bed is very irregular in both thickness and structure.

In Washington Township, where present, the Lower Freeport coal is thin, shaly, and therefore worthless. The best fuel found on this horizon in the county is on the property of Harvey Snoots, about three-fourths of a mile east of the Salem School in the southern part of Madison Township. There the coal is mined in a small way for local use. Good coal, 3 feet thick, overlies 3 inches of bone coal. The coal was sampled at this place for chemical analysis. The bed lies directly upon a sandstone which is so solid and smooth that it is used as the floor upon which the cars are run. Clay is wanting. The area of the thick coal is not definitely known, but it appears to include only parts of two farms. In Section 21, Madison Township, the coal was formerly mined on the farms of Harmon T. Ridgway and H. H. King. In this locality the bed lies about 40 feet above the Middle Kittanning coal and is reported to be 3 feet 4 inches in thickness. The area is small. Only thin deposits of shaly coal were observed on this horizon in Adams, Salem, and Monroe townships.

Economic Value

The Lower Freeport coal adds but little to the fuel wealth of Muskingum County as only two small areas in which the coal has sufficient height for regular drift mining were observed along the entire outcrop. At several other places, however, small quantities of coal may be obtained along stream beds where the covering has been largely removed by erosion.

The Lower Freeport coal at the mine of Harvey Snoots was sampled by R. E. Lamborn and the writer in July, 1917. The sample was taken well under cover where the coal was bright and solid and where the mine was dry. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	70.03	Moisture	5.35
Hydrogen	5.85	Volatile matter	44.46
Oxygen	13.77	Fixed carbon	43.33
Nitrogen	1.40	Ash	6.86
Sulphur	2.09		
Ash	6.86		

Calorific value { 7,099 calories. / 12,778 B. t. u.

Air drying loss of moisture, 1.9 per cent.

Fusion temperature of ash { incipient, 1,153° C. / complete, 1,190° C.

The Lower Freeport is a hard coal tending somewhat towards the cannel type. Owing to its oily nature it ignites readily and burns with a long flame. Its heating value is on par with that of other coals in the county, and its ash is light and powdery under ordinary conditions of firing. The chief use of this fuel is for domestic purposes, for which it is well liked. The Lower Freeport clay has but little ceramic value.

UPPER FREEPORT SANDSTONE

The Upper Freeport sandstone may be found in some state of development in every township in Muskingum County in which it is due. This includes all or parts of Clay, Newton, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Springfield, Washington, Perry, Falls, Muskingum, Madison, Salem, Adams, Monroe, and Highland townships. The normal position of the member is between the Lower Freeport coal and the Bolivar clay, but in parts of the area it extends considerably beyond these limits. Further, it often coalesces with the underlying Lower Freeport sandstone, under which condition the main part of the interval from the Middle Kittanning coal to the Upper Freeport coal is sandstone. The member may be represented by thick beds of coarse sandstone, by thinner beds of such material interstratified with shale, or by shaly sandstone that gradates into shale. It is a micaceous, poorly-cemented sandstone in which the cross-bedding planes are rather prominent.

The stratigraphy of the member in the southern part of the county is shown by the following record taken along the road in Section 14, Newton Township:

		Ft.	In.
Shale		4	--
Coal blossom, *Upper Freeport*		--	6
Clay and covered		12	--
Sandstone, shaly	*Upper Freeport*	16	--
Sandstone, with parts covered	*Upper Freeport*	30	--
Coal blossom, *Lower Freeport*		--	3

The Upper Freeport is a friable, micaceous, rather coarse-grained sandstone, which usually disintegrates rapidly on weathering. Clay, with iron, calcium, and magnesium compounds are the principal cementing agencies. The quality of the material is too poor for building stone or for glass sand. Possible uses when the rock has been properly prepared are for molding sand and for abrasive purposes.

BOLIVAR CLAY

A thick bed of plastic clay, in which are frequently found irregular or lens-like masses of flint clay, is present in local areas in Muskingum County. It lies either directly on or only a few feet below the Upper Freeport limestone. In many places a smut streak or a thin bed of shaly coal is found just above the clay. This bed is correlative with the great Bolivar clay of Pennsylvania, which is so largely worked in the vicinity of Connellsville and Bolivar. The horizon of the member is above drainage in parts or all of Clay, Newton, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Perry, Washington, Salem, Madison, Adams, Monroe, and Highland townships, but the deposits are usually small and somewhat isolated.

The position of the Bolivar clay is shown in the following record, taken in Section 24, Brush Creek Township:

	Ft.	In.
Sandstone, soft, *Mahoning*	14	--
Clay, light, *Upper Freeport*	3	6
Limestone, nodular, *Upper Freeport*	--	6
Clay with some small limestone nodules, *Bolivar*	3	--
Shale and shaly sandstone	33	--
Shale, dark, carbonaceous, horizon of *Lower Freeport* coal	--	2

Small deposits of flint clay on the Bolivar horizon were observed at a few places in the southern part of the county. Plastic clay, however, is the common representative of the member. The material is often so ferruginous that on weathering it has a pink or red color. A section well illustrating the general stratigraphy of the Bolivar clay was obtained at the No. 1 plant of the Burton-Townsend Brick Co. at Zanesville. The record is given below:

		Ft.	In.
Coal, *Upper Freeport*		--	3
Clay, dark, siliceous, *Upper Freeport*		2	--
Clay, with nodular *Upper Freeport* limestone		3	6
Shale, gray		4	--
Sandstone, shaly		4	--
Shale, dark, carbonaceous, coal horizon		--	6
Clay, light, part siliceous, *Bolivar*		3	4
Smut streak		--	¼
Sandstone, light, clay-bond	*Upper Freeport*	1	--
Sandstone, shaly		7	--

In this locality the Bolivar clay lies farther below the Upper Freeport limestone than it does in most places, and is less flinty in character.

Otherwise all the members of this general horizon are represented in about their correct positions. Deposits of flint clay as well as plastic clay were observed on the horizon along Salt Creek in Salt Creek Township. The conditions in the northeastern part of the county are about as represented in the following record, taken along the road one-fourth mile north of Sonora in Perry Township:

	Ft.
Clay, plastic, *Upper Freeport*	3
Clay with nodular *Upper Freeport* limestone	1
Clay with parts covered, *Bolivar*	7
Sandstone and covered	20
Sandstone, massive, soft — *Upper Freeport*	10
Covered	10
Limestone, nodular, *Lower Freeport*	1

In the northeastern part of the county the Bolivar clay is often wanting, and where present is usually plastic in character. Small deposits of impure flint clay were noted in only a few places. The position of the member, with few exceptions, is just below the Upper Freeport limestone.

The Bolivar clay in Muskingum County scarcely needs be considered for its ceramic value as the deposits are uncertain in extent, and as the material is poor in quality. Although both flint and plastic clays are present on the horizon the main volume of the material is of the softer variety. Nodules of marly limestone and impure siderite are common impurities of the plastic clay, which in general is also siliceous in composition. The hard clay is flinty in character and slakes on weathering into sharp angular pieces. The clay under cover has a mottled or banded light-gray color, but that affected by weathering agencies has a yellow, pink, or red color, owing to the presence of iron oxide pigments. Small quantities of the plastic variety are used for bonding by the Burton-Townsend Brick Co.

UPPER FREEPORT LIMESTONE.

The Upper Freeport limestone is a rather conspicuous stratum in local areas in Muskingum County. It is the fifth well-defined limestone stratum in the Allegheny formation of this county. This limestone lies 2 to 12 feet below the Upper Freeport coal. The average interval is about 7 feet. The limestone, however, is far more steady than the coal, hence it forms a stratigraphic unit of value. At its best the limestone is hard, compact, and light-colored. As a usual thing, however, especially along the outcrop, the rock is sufficiently ferruginous to be of a buff color, and in places even to be classed as an impure iron ore. The limestone is non-fossiliferous and appears to be of fresh-water origin. Further, it is nearly always more or less brecciated where the deposits have fair volume. In many places the member is represented only by small nodules of limestone, or impure iron ore bedded in clays.

The Upper Freeport limestone is best represented in Clay, Newton, Brush Creek, Harrison, Wayne, Perry, and Monroe townships, although it is present also in Bluerock, Salt Creek, Salem, Adams, and Highland townships. The following record, taken in Section 35, Newton Township, shows the general stratigraphy of this member:

	Ft.	In.
Shale	10	--
Coal, *Upper Freeport*	2	6
Covered	3	--
Limestone, light-gray, brecciated, *Upper Freeport*	3	4

In this locality the Upper Freeport limestone retains a fair thickness over a considerable area. The stone is more or less stained with iron oxides.

The Upper Freeport member is rather persistent in Harrison and Bluerock townships, but the deposits are more often marly and nodular masses of limestone in clay than a well-stratified bed of this material. The position of the bed is 5 feet below the Upper Freeport coal in Section 18, Wayne Township. In this locality the rock is a blue, nodular limestone, much resembling many of the beds in the Conemaugh formation. In a few places in this township nodules more than 1 foot in thickness were observed on the horizon. The member in local areas in Perry Township is a well-stratified bed of limestone, varying from 1 to 2 feet in thickness. Along the road that leads from the small stream to the ridge south in the northern part of Washington Township, the Upper Freeport limestone has a thickness of 1 foot, and lies 4 feet below the coal.

The general stratigraphic position and average condition of the Upper Freeport limestone in Salem Township is shown in the following record, taken along the road in the southern part of Section 23:

	Ft.
Coal blossom, *Upper Freeport*	2
Clay, part covered	11
Clay with nodules of *Upper Freeport* limestone	2
Sandstone, massive, *Upper Freeport*	33
Coal, shaly, *Lower Freeport*	1

The Upper Freeport limestone is rather steady, and in Adams and Highland townships is found in about the same conditions as shown above. In Monroe Township patches of well-stratified, but decidedly nodular limestone, from 6 inches to 1 foot 6 inches in thickness were observed. Its position there is 6 to 12 feet below the Upper Freeport coal.

Economic Value

The chief value of the Upper Freeport limestone in Muskingum County is the lime that it furnishes to the soil along its line of outcrop. Its value for agricultural lime, road metal, or concrete stone is very small.

A—View at the No. 2 plant of the Burton-Townsend Brick Co. at Zanesville. The material just below the shed is molding sand, the dark layer farther down is the Middle Kittanning coal, and the light substance above water level is the Oak Hill clay.

B—Dog teams are used for hauling coal in many low mines in the Middle Kittanning and Lower Kittanning coals near Zanesville.

PLATE IX.

A—Molding sand pit of the Glacial Sand & Gravel Co., Zanesville. The thickness in places is 10 feet; the upper 2 feet of soil and clay are rejected. The sand is so fine that it is classed as No. 1.

B—One view in the molding sand pit of the Ayers Mineral Co., near South Zanesville.

UPPER FREEPORT OR NO. 7 COAL AND CLAY

Stratigraphy and Extent

The Upper Freeport coal, the youngest member of the Allegheny formation, is unsteady in both thickness and extent in Muskingum County. In many places the horizon is marked only by a smut streak of coal or by its associated clay. In this county the Upper Freeport coal lies, on the average, about 93 feet above the Middle Kittanning coal and about 100 feet below the Cambridge limestone. In a part of the area the coal is either directly overlain by the massive Mahoning sandstone or is separated from this stratum by shales varying from 1 to 15 feet in thickness. This sandstone in local areas often replaces a part or all of the coal. However, it does not follow that all the thinning of the coal is occasioned through replacement, for in large areas where the coal is only a smut streak or only a few inches of impure fuel the bed is directly overlain by shales many feet in thickness. The small thickness of the coal at such places is due to lack of deposition of vegetation or to its removal by currents of water.

Clay Township.—The Upper Freeport coal is above drainage in all of Clay Township, but the horizon in most of the area is marked only by a smut streak or by a few inches of impure coal. A few pockets of inferior grade fuel are present in Section 1.

Newton Township.—In sections 23, 25, 35, and 36, Newton Township, the Upper Freeport coal has good thickness and has been mined in a desultory way for local use. A small area of this coal is also present in Section 1. The bed is usually made up of both bituminous and cannel coal and is overlain by black, carbonaceous shale. The bed passes above the summits of the hills west of Moxahala Creek. At the country mine of John Towning, in Section 36, the following measurements were obtained:

	Ft.	In.
Shale, black, carbonaceous	1	--
Clay, black	--	1
Coal, good, *Upper Freeport*	3	6
Clay, black	--	1
Clay, light	1	--

In this locality the coal is reported to be variable in thickness and character. The mining has been confined to small country banks. The coal on the farm of George Good is reported to be 2 feet 6 inches in thickness. It extends westward into Section 35, where the thickness reported is from 2 to 4 feet. On the property of J. W. Wigton, in the eastern part of Section 23, the following record was obtained:

		Ft.	In.
Shale, black, tough		6	--
Coal, cannel	*Upper Freeport*	2	8
Coal, bituminous	*Upper Freeport*	2	1
Sandstone, shale, and covered		90	--
Coal blossom, *Middle Kittanning*		3	--

In a prospect opening on the property of William Young, in the central part of Section 23, the structure and thickness of the Upper Freeport coal are as given below:

		Ft.	In.
Shale, black		3	--
Coal, cannel, bony	*Upper Freeport*	4	--
Coal, cannel, good		3	8½
Coal, bituminous		1	7
Clay, light		2	--

The area of coal, in Section 23, is rather small as the bed lies near the summit of the main ridge. From outcrop observations there is a small pocket of good coal in Section 25. At an abandoned mine on the farm of A. A. Laisure the bituminous coal was 3 feet 6 inches in thickness. At some places this is overlain by 2 or 3 feet of impure cannel coal. But little mining has been done in the area. In sections 13, 14, 24, and 26 the Upper Freeport coal from outcrop observations appears to be thin and impure. On the high knob in the southeastern corner of Section 1, on the land of David Jones, 4 feet of this coal is reported. The area, however, is small.

Brush Creek Township.—The largest known area of Upper Freeport coal in Muskingum County is in the vicinity of Cannelville in Brush Creek Township. The coal was formerly mined for railroad shipment, but at present it is worked only for local consumption. The upper part of the stratum is often cannel coal of fair quality. The bed is subject to sudden changes in thickness, often decreasing in a short distance from several feet of good coal to a few inches of soot or impure material. At the old Rose Hill mine, in Section 26, the structure of the coal is as follows:

		Ft.	In.
Shale		3	--
Coal, cannel	*Upper Freeport*	2	--
Coal, bituminous		4	1
Clay		2	--

In this locality the thickness of the bituminous coal is rather constant, but that of the cannel coal is variable and often changes to carbonaceous shales. At the mine of the Pan-American Coal Co. the bituminous layers are about 4 feet in thickness and of good quality. The structure of the stratum at the country mine of Ira Cox, in the southern part of Section 26, is as follows:

	Ft.	In.
Shale, black, carbonaceous	2	1
Coal, bituminous, *Upper Freeport*	4	1
Clay, plastic	1	--

In the western part of Section 6, south of the tributary of Brus Creek, the Upper Freeport coal is generally thin and impure, bein represented more by bony shales than by coal. In the central part,

however, on the property of O. L. Wilson, the coal is about 4 feet in thickness and is bituminous in character. The bed is overlain by black carbonaceous shales. On the farm of Ora Platcher in the southeastern part of Section 6, the thickness of the Upper Freeport coal is from 3 feet 9 inches to 4 feet. At the country mine of J. Payne, which is located on Goose Run in the northern part of Section 7, the Upper Freeport coal is bituminous and from 3 feet 10 inches to 4 feet 4 inches in thickness. The bed is reported to be rather steady along this stream and along Brush Creek in sections 5 and 8. Where mined for local use on the property of Longstreth and Harrop, in the southeastern part of Section 5, the coal is on the average 3 feet 10 inches in thickness and is bituminous. The acreage of coal reported in this vicinity is rather large. On the land of E. C. Swingle, in Section 24, the following rocks were measured:

	Ft.	In.
Sandstone, shale, and covered	45	--
Coal, bituminous	3	8
Coal, cannel — *Upper Freeport*	--	5
Clay and covered	3	--
Limesto e, light, brecciated, *Upper Freeport*	2	--
Sandstone and covered	35	--
Sandstone, massive	15	--
Shale, light	16	--
Coal blossom, *Middle Kittanning*	3	--

In the northeastern part of Section 25 the Upper Freeport coal is from 2 feet 6 inches to 3 feet in thickness, and of good quality. This bed is again mined on the farm of Florence Bash, in the central part of Section 16, where the following record was taken:

	Ft.	In.
Shale	5	--
Coal, bony	--	4
Coal, good — *Upper Freeport*	3	4
Clay, shale, and covered	75	--
Coal, bony	--	6
Coal, good	1	8
Shale — *Middle Kittanning*	--	1
Coal, good	1	4½

A heavy blossom of Upper Freeport coal was noted on the land of J. W. Welch, in the western part of Section 6, north, but the thickness of the solid fuel was not determined. Railroad mines were formerly operated in this coal south of Sealover, in Section 13, and the thickness reported is from 2 to 6 feet. The bed at this place lies 88 feet above the Middle Kittanning coal, and about 10 feet below the massive Mahoning sandstone. Small local mines were worked on the land of J. I. Swingle on Duncan Run, in Section 22. The bed is stated to be about 4 feet in thickness in this locality, but the area is rather small.

Harrison Township.—The Upper Freeport coal is above drainage

in Harrison Township along the Muskingum River, as far downstream as Stone, in Section 30, and along its tributaries well towards their headwaters. Fuel has been mined from this bed at Stone for more than 60 years, but the main workings are at present abandoned. The Bluerock coal, as it was called, had a wide reputation for domestic purposes, and was transported both by rail and by water to points along the Muskingum River. The principal field at present is along Bluerock Creek in Section 11. North of this the coal is patchy and is generally only a few inches in thickness. The average thickness of the good coal at Stone is reported to be 4 feet 4 inches. The cannel coal is absent in much of the area. Rather large wagon mines are operated on the property of T. Olden, in Section 11, where the bed was sampled for chemical analysis. The structure of the coal is given below:

		Ft.	In.
Shale		15	--
Coal, good	*Upper Freeport*	1	3
Shale with much pyrite	*Upper Freeport*	--	1½
Coal, good	*Upper Freeport*	2	10
Clay, siliceous		3	--

The member also outcrops along Bluerock Creek southeast of the Olden property. A good acreage of unworked coal is reported in this vicinity. The coal is very bright, clean, and quite free from sulphur balls or lenses. This stratum was formerly mined also near the mouth of Little Bluerock Creek, where it is reported to be 4 feet in thickness, and to be of excellent quality. Near the mouth of this stream the coal has been mined on the property of Lora Thomas and H. A. Merriam, and is reported to be 2 to 5 feet in thickness. On Back Run, in the vicinity of the Back Run School, the coal is only 6 inches in thickness, and is underlain by 15 feet of clay, a part of which is colored by iron oxides. Near the head of this stream on the property of L. L. Dozer, in Section 30, west, the Upper Freeport coal, 4 feet 6 inches in thickness, is reported to have been found by the drill at a depth of about 50 feet. On Duncan Run, in Section 21, small mines have been operated on the property of S. M. Beisser and on that of W. T. Hutson. The thickness of the bed is stated to be 2 to 4 feet. A small pocket of workable coal is also present on the land of R. L. Dearnbarger in Section 20. Near Philo the bed is thin and of little value.

Bluerock Township.—The horizon of the Upper Freeport coal and clay is above drainage along the Muskingum River in Bluerock Township from the northern boundary to Section 29, where it passes below the bed of the river. Coal of value is reported to have been found by the drill in a small area in sections 29 and 32. North of this, where the bed is exposed, the coal is seldom more than a few inches in thickness, and is shaly in character. The clay, however, is rather steady and has good volume.

Salt Creek Township.—The Upper Freeport coal is very unsteady in Salt Creek Township, where the member is above drainage along the streams in the western part. The bed is mined at a number of places and furnishes the main supply of local fuel. South of the Elliott School the coal may be seen in the bank of Manns Fork of Salt Creek near the mouth of Kent Run. Small areas of good coal are also present in Section 28, where the following record was obtained in a small mine on the C. H. Spangler property:

		Ft.	In.
Shale, gray, siliceous		5	--
Coal	*Upper Freeport*	2	--
Shale		--	2
Coal		1	--
Shale, carbonaceous		1	6

The deposit extends northward into Section 21, where it measures 2 feet 10 inches on the land of A. G. McConaha. Coal is also mined for the local trade on the P. W. Davis property in Section 20. On the J. Winters land, in the eastern part of Section 8, the thickness of the Upper Freeport coal in a small mine is 3 feet 2 inches. Small quantities of this coal have also been mined in the vicinity of Chandlersville, where the bed passes below drainage. The thickness of the member at this place is reported to be about 3 feet. Along Salt Creek, in the northern part of the township, the coal is generally very thin, but the associated clay has good thickness, and varies from 3 to 8 feet.

Wayne Township.—The horizon of the Upper Freeport coal and clay is above drainage in all of Wayne Township, but the coal has sufficient thickness for mining only in sections 1, 2, 9, and 10. The clay is steady, but it is of inferior quality. The measurements obtained at the Greiner and Keeton mine, located in Section 2, are given below:

		Ft.	In.
Shale, lower part dark		8	--
Coal, good	*Upper Freeport*	3	10
Shale		--	1
Coal, good		2	2
Clay		--	¼
Coal, good		--	4
Clay		2	--

The coal is mined in a small way for railroad shipment. The fuel is shot off the solid and hauled by mule power. The area was worked in a haphazard way many years ago, but a considerable quantity of good coal is yet available. The operators report that the thick coal in this field is about 1½ miles long, extending north and south, and about one-half mile wide. Frank Borden, whose property is just east of the Greiner and Keeton mine, was also preparing to mine coal for railroad shipment in 1917. Near the outcrop the good coal measures

5 feet 5 inches in thickness. South of the Ohio River & Western Railroad in Section 9, a railroad mine is operated by William A. Warner. The coal at this place has the following general thickness and structure:

		Ft.	In.
Shale		5	--
Coal	*Upper Freeport*	4	--
Shale	*Upper Freeport*	--	2
Coal	*Upper Freeport*	2	4
Clay		2	--

There are from 15 to 20 men regularly employed at the mine. The coal is hauled by mule power. In the remainder of the township the Upper Freeport horizon is better represented by clay than by coal.

Washington Township.—One of the first fields of Upper Freeport coal worked in Muskingum County is near Jackson, in the southeastern part of Washington Township. Although the best of the field is exhausted considerable fuel is yet obtained from small mines. The coal is delivered by wagon to Zanesville and to the farmers of the adjacent country. The covering is everywhere shallow and consequently in many places the roof is so weak that drift mining is unsafe. Some coal is obtained by stripping. The bed in this field varies from 3 feet to 5 feet 6 inches in thickness. The following measurements of the Upper Freeport coal were obtained in a small mine located along the little stream, about three-fourths mile northwest of the Jackson School:

		Ft.	In.
Shale, gray, siliceous		2	--
Coal, bony	*Upper Freeport*	--	2
Coal, good	*Upper Freeport*	2	4
Clay	*Upper Freeport*	--	4
Coal, good	*Upper Freeport*	2	--
Clay, gray		2	--

Along the National Road, about three-fourths mile southwest of the Jackson School, coal is mined in a small way on the land of H. C. Greiner. The measurements of the bed are given below:

		Ft.	In.
Shale, siliceous		5	--
Coal, bony	*Upper Freeport*	--	9
Coal, good	*Upper Freeport*	1	9
Clay	*Upper Freeport*	--	2
Coal, good	*Upper Freeport*	2	1
Clay, siliceous		1	--

Along the National Road, south of the Pleasant Grove School, the coal lies near the summit of the hills or on the 900-foot contour, and is mined on the property of George Handchy for local trade. Its thickness and structure are given below:

		Ft.	In.
Shale, gray, siliceous		4	--
Coal, bony	*Upper Freeport*	--	8
Clay		--	1½
Coal, good		1	2
Clay		--	2
Coal, good		2	4
Clay, siliceous		2	--

In the northern part of the township the Upper Freeport coal is everywhere thin and impure and the clay is not especially conspicuous.

Perry Township.—The main body of the Upper Freeport coal in Perry Township is in the vicinity of Sonora, where the bed has been mined for many years. The coal varies from 2 to 4 feet in thickness and is very unsteady in both thickness and quality. It was formerly mined in sections 6, 7, and 8, but the areas are now practically exhausted. The bed is worked, however, in a small way on the farm of C. H. Bunting, in Section 5, where the following record was obtained:

		Ft.	In.
Shale, siliceous		1	--
Coal, bony	*Upper Freeport*	--	4
Coal, good		1	10
Shale		--	2
Coal, good		1	1
Clay, siliceous		1	--

At present the most promising area is south of Sonora where a few mines are operated in a small way. At the mine of W. A. Dailey the Upper Freeport coal was sampled for chemical analysis and has the following thickness and structure:

		Ft.	In.
Shale		4	--
Coal, bony	*Upper Freeport*	--	9
Coal, good		1	6
Clay		--	1½
Coal, good		1	9
Clay, siliceous		1	--

About 1 mile south of Peregory School, in the southwestern corner of the township, coal is mined for local trade on the farm of Milton Waltermire. A section of the coal follows:

		Ft.	In.
Shale, black		--	6
Coal, bony, left for roof	*Upper Freeport*	1	--
Coal, good		2	10
Clay		--	2
Coal, good		--	5
Clay, siliceous		1	6

The coal is above drainage along Salt Creek in the eastern part of the township, but no deposits of value were observed. The asso-

ciated clay is much steadier than the coal, but it is too impure for ceramic use. The chief value of the Upper Freeport coal in Perry Township is to supply local needs.

Union Township.—In Union Township the Upper Freeport coal is above drainage only along Georges Run, in sections 6 and 15, and is mined in a small way, in Section 15, on the Dwight Secrist property. The structure of the bed is given below:

		Ft.	In.
Shale		2	--
Coal, good	*Upper Freeport*	1	3
Coal, bony		--	1
Coal, good		--	4
Clay		1	--

The coal is reported to have a maximum thickness of 2 feet 1 inch. The area is small. Cannel coal was reported in a well 350 feet below the surface on the Richard Rice farm, 2½ miles south of New Concord.

Salem Township.—The Upper Freeport coal and its associated clay are above drainage along Salt Creek and its tributary, Prairie Fork, in the southern part, and along Symmes Creek and its tributary, South Branch, in the northwestern part. In places the member is difficult to follow as it is replaced locally by massive sandstone. Coal with sufficient thickness for mining was observed only in Section 23, where the measurements given below were obtained in a small drift mine:

		Ft.	In.
Shale, siliceous		1	--
Coal	*Upper Freeport*	1	10
Shale		--	1½
Coal		1	4
Clay		1	--
Covered		4	--
Sandstone, *Upper Freeport*		20	--

From outcrop indications the area is small. The bed lies about 90 feet below the Cambridge limestone and about 45 feet above the Lower Freeport coal.

Madison Township.—But little needs be said in regard to the Upper Freeport coal in Madison Township as the bed is thin and in places absent. The horizon lies near the summits of the main ridges in all of the area except the extreme western part. The position of the member is 80 to 95 feet above the Middle Kittanning coal.

Adams Township.—The horizon of the Upper Freeport coal is above drainage along the courses of all the streams in Adams Township, but no coal of value is known. The usual representative is a smut streak underlain by a few feet of light plastic clay. In some places even these are replaced by massive sandstones.

Monroe Township.—The most northern area of Upper Freeport coal in Muskingum County is a small field about 1 square mile in ex-

tent, south of Otsego, in Monroe Township. The member lies well above drainage in all of the township, but its associated clay is by far the most conspicuous feature. The massive overlying Mahoning sandstone, especially in the southern part, forms many bold cliffs and gorge-like ravines. But little mining has been done in this coal as the Middle Kittanning bed is more available and as the fuel is of superior quality. The coal has been prospected by a short entry on the farm of D. W. Welker, and is reported to be very hard and 3 feet 6 inches thick. South of this in the same section, the following record was obtained on the farm of C. W. Welker:

		Ft.	In.
Shale, lower part dark		16	--
Coal, bony	*Upper Freeport*	--	4
Coal, hard, with few thin partings		2	8
Clay shale		--	½
Coal		--	1
Clay shale		--	½
Coal, good		--	5
Clay		1	6
Coal, reported thickness		1	6

The coal is hard and dense and below the average in quality. In the southeastern part of Section 19 small mines were formerly operated on the property of F. E. Brill. In this locality the coal is reported to be made up of two benches, separated by 1 foot 6 inches of clay. The upper bench is stated to be 3 feet in thickness and the lower bench 1 foot 6 inches. This coal has also been located by the drill near the Granite Knob School in Section 20. The coal with sufficient thickness for regular drift mining was not found elsewhere in Monroe Township.

Highland Township.—But little needs be said concerning the Upper Freeport coal in Highland Township, except that the horizon is above drainage along White Eyes Creek and its tributaries in the northern part. No coal of value was found along the outcrop and none was reported under cover after drilling for oil and gas.

Economic Value of Upper Freeport Coal

The fitful and inconstant character of the Upper Freeport coal makes mining in a large way hazardous, unless the areas are thoroughly prospected by the drill, which adds considerably to the expense. In this county only country mines with small outputs of fuel are being operated at present, except along the Ohio River & Western Railroad in Wayne Township, where a few railroad mines are worked. The roof of the mines in most of the area is either an impure coal or a hard carbonaceous shale, both strong and durable. In a few local areas the Mahoning sandstone lies on the coal, or even replaces a part of it. The general roof conditions are good. The floor of the coal is a soft plastic clay, in places many feet in thickness. In well-drained

mines this is not especially troublesome, but in wet mines it forms muddy entries and insecure footings for posts and pillars, often resulting in squeezes and falls. The bed is, with few exceptions, broken by partings of clay or shale, some of which are frequently highly charged with nodules of pyrite. In a general way the Upper Freeport coal is broken into two benches of bituminous coal overlain with a bench of cannel coal, which in most of the area is nothing more than highly carbonaceous shale. The average of all the mine measurements taken in this county shows nearly 4 feet of good coal. Counting 70 per cent of the fuel available in mining, such a bed will yield approximately 5,040 tons per acre. The general quality of the Upper Freeport coal is shown by the following analyses:

Mine of Bluerock Coal Company, Harrison Township, Muskingum County. Good sample cut from a section 12 by 7 inches, by B. A Eisenlohr in July, 1907.[1]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	67.74	Moisture	4.89
Hydrogen	5.53	Volatile matter	42.35
Oxygen	13.42	Fixed carbon	44.88
Nitrogen	1.17	Ash	7.78
Sulphur	4.36		
Ash	7.78		

Calorific value { 6,944 calories. 12,499 B. t. u.

The Upper Freeport coal in the mine of T. Olden, which is located in Section 11, Harrison Township, was sampled by the writer in September, 1917. The sample was cut from the bed where the covering was heavy and the coal bright and solid. Although the mine was somewhat wet the sample was taken in a dry place and is considered representative. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	67.98	Moisture	4.27
Hydrogen	5.36	Volatile matter	45.63
Oxygen	11.28	Fixed carbon	41.07
Nitrogen	1.12	Ash	9.03
Sulphur	5.23		
Ash	9.03		

Calorific value { 6,967 calories. 12,541 B. t. u.

Air drying loss of moisture, 1.2 per cent.

Fusion temperature of ash { incipient, 1,085° C. complete, 1,139° C.

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 257.

Mine of Maynard Bros., Brush Creek Township, Muskingum County. Sample fair. Cut from section, 12 by 4 inches, by B. A. Eisenlohr, in August, 1907.[1]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	68.27	Moisture	4.72
Hydrogen	5.55	Volatile matter	43.47
Oxygen	12.30	Fixed carbon	44.25
Nitrogen	1.32	Ash	7.56
Sulphur	5.00		
Ash	7.56		
Calorific value	7,046 calories. 12,683 B. t. u.		

Zanesville Coal Company's mine, Wayne Township, Muskingum County. Sample fair. Cut from a section, about 12 by 4 inches, by B. A. Eisenlohr, in August, 1907.[2]

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	64.81	Moisture	5.11
Hydrogen	5.11	Volatile matter	35.50
Oxygen	12.39	Fixed carbon	46.79
Nitrogen	1.25	Ash	12.60
Sulphur	3.84		
Ash	12.60		
Calorific value	6,558 calories. 11,804 B. t. u.		

A sample of Upper Freeport coal was taken by R. E. Lamborn and the writer in July, 1917, at the drift mine of W. A. Dailey, which is located about 1 mile southeast of Sonora in Perry Township. The sample was taken at the head of the entry, but the coal was somewhat damp. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	65.71	Moisture	9.28
Hydrogen	5.60	Volatile matter	38.90
Oxygen	15.91	Fixed carbon	43.63
Nitrogen	.97	Ash	8.19
Sulphur	3.62		
Ash	8.19		
Calorific value	6,584 calories. 11,851 B. t. u.		

Air drying loss of moisture, 4.1 per cent.

Fusion temperature of ash { incipient, 1,125° C. complete, 1,153° C.

Excluding the cannel coal of the upper bench, the fuel in the main bed of the Upper Freeport member is rather high in volatile matter,

[1] Geol. Survey Ohio, 4th Ser., Bull. 9, pp. 257-8. [2] *Idem*, p. 258.

and in a way intermediate between an ordinary bituminous and a true cannel coal. In places, especially in the northern part of the county, the coal in all or a part of the bed is very hard, having a flinty or curly appearance. In Harrison and Brush Creek townships thin layers of cannel coal or dense carbonaceous shale are common features in the benches of bituminous coal. The cannel coal overlying the main bed is more or less impure, and in fact it gradates laterally into dense, highly carbonaceous shales. The best of the coal is in the Brush Creek and Bluerock basins, especially the latter. Of this Dr. Orton says:[1]

> The Blue Rock coal, as it now appears, is in marked contrast to the general product of the bed elsewhere. It is a typical pitch coal, clear and bright to a higher degree than any other Ohio coal. In fact it is nearly as clear as anthracite. No mineral coal is found in the present product of the mine. The proportion of sulphur is excessive, constituting the only drawback upon the otherwise high quality.

Owing to the high content of volatile matter, the coal kindles easily and burns freely, thus being especially well fitted for domestic use. It is not a sooty fuel even where tending strongly towards the cannel type. The coal is rather tender, hence it does not bear shipment or storage well. The ash which is dark-gray causes some trouble from clinkering as it fuses at rather low temperatures. The sulphur content of the fuel is always high, this element being combined mainly with iron as pyrite or marcasite. The Upper Freeport coal is well liked for household use as well as for steam generation. It cokes readily, forming a product with excellent structure, but its high sulphur content excludes it from the market.

Economic Value of Upper Freeport Clay

The Upper Freeport clay which lies directly below the Upper Freeport coal has an average thickness, in Muskingum County, of approximately 5 feet. In many places this member and the Bolivar clay are merged into one bed or are separated only by the Upper Freeport limestone, under which condition the total thickness varies from 10 to as much as 20 feet. The Upper Freeport clay extends across the county with few wants, but it varies considerably from place to place in both thickness and quality. It is a light-colored plastic clay with fair bonding properties. The material, especially in the lower part of the bed, is very siliceous. The chief detrimental components are iron oxide, lime, and magnesia, which occur in the main as carbonates in the form of nodules. It is of little importance at present in Muskingum County, as such large quantities of much better material are present on the Lower Kittanning and Tionesta horizons. Its chief use is for common ware or for bonding purposes. At the No. 1 plant of the Burton-Townsend Brick Co., near Zanesville, small quantities of this clay are added to the shales used in the manufacture of paving block.

[1]Geol. Survey Ohio, Vol. V, p. 881.

CHAPTER IV

CONEMAUGH FORMATION

The Conemaugh formation is present in its full thickness in the southeastern part of Muskingum County and its basal beds are found as far west as the Muskingum River and Moxahala Creek. The average thickness of the formation is 377 feet. Taken as a whole, the rocks of the Conemaugh formation differ markedly from those of the underlying Allegheny formation, but they change gradually from one division to the other. The line of separation is somewhat arbitrary as it is based more on the deposition of vegetable matter in the form of coal than on distinct variation in the character of the rocks, or on the changes in the types of marine life, or on the evidence afforded by crustal movements. In the Allegheny formation thick coal beds, gray siliceous shales, soft micaceous sandstones, and light plastic clays are conspicuous; whereas in the Conemaugh formation highly-colored argillaceous shales, shaly ripple-marked sandstones, and nodular and marly limestones are especially prominent. The rocks of the Conemaugh formation are closely allied in every respect with those of the overlying Monongahela formation, except that in the Conemaugh, the coal beds are much thinner and less valuable than those in the Monongahela. As far as this region is concerned, the separation of the rocks into these formations is also purely arbitrary. In general the rocks in the upper half of the Conemaugh differ greatly from those in the lower half. Highly-colored clay-like shales, marly limestones, and nodular and irregularly bedded non-fossiliferous limestones at once stand out as the conspicuous beds of the upper half of the formation; whereas gray siliceous shales, shaly ripple-marked sandstones, and fossiliferous limestones are the prominent beds in the lower half. In the main, the rocks of the upper half of the formation are of fresh-water origin whereas those in the lower half are of marine derivation.

The Ames and Cambridge limestones of the Conemaugh formation, although usually thin, are of wide extent and are the main benches of reference for the stratigrapher. These beds enter Ohio from Pennsylvania, cross the State, and extend into Kentucky and West Virginia. The Brush Creek limestone is also widely known, although the bed is fitful and inconstant in Muskingum County. Other Conemaugh limestones of some prominence in this area are Portersville, Skelley, Summerfield, and Pittsburgh. The Mahoning, Anderson, and Harlem coals are remarkably persistent for thin beds, but they have little value economically. Some of the sandstones which are so conspicuous

along their outcrops in Muskingum County become the reservoirs for oil and gas in southeastern Ohio. As mineral resources the beds of the Conemaugh formation in this county are of little value as the limestones and coals are thin and as the clays and shales are of no great ceramic importance. Owing to the abundance of regularly bedded, nodular, and marly limestone, however, the soils derived from the decay of the Conemaugh rocks are rich in lime and magnesia, and are therefore well fitted for growing blue grass, nitrating legumes, and many cereals. Rocks of this age are present above drainage in Meigs, Bluerock, Harrison, Brush Creek, Clay, Newton, Rich Hill, Salt Creek, Wayne, Union, Perry, Washington, Highland, Salem, Madison, Adams, and Monroe townships.

MAHONING HORIZON

Condit has written as follows concerning the Mahoning horizon:

The lower 60 or 70 feet of the Conemaugh formation consists of sandy shale or sandstone in two parts, with a break near the middle, occupied by coal and underlying limestone. The "Upper Mahoning" and "Lower Mahoning" have been used as names for these sandstone beds in Pennsylvania and West Virginia; the coal is called the Mahoning. Dr. White, in his description of the "Conemaugh series," speaks of the "Mahoning sandstone stage" which he divides as follows:

Upper Mahoning sandstone,
Mahoning coal,
Thornton fire clay,
Mahoning limestone,
Lower Mahoning sandstone.

Near Morgantown, West Virginia, shales rich in marine fossils overlie the Upper Freeport coal. Dr. White has named these the Uffington shales. It is not unusual to find shales occupying much of the Lower Mahoning horizon in Ohio, but no marine fossils have been discovered in them.

With the thinning of the Conemaugh formation westward in Ohio, some of the strata prominent in Pennsylvania disappear. The Upper Mahoning is seldom a massive sandstone in the Ohio outcrop and is more often shaly sandstone or sandy shale. The Mahoning coal, with underlying clay and limestone, is present in the e stern part of the state, where it has been variously designated as the "Groff vein", "Salineville Strip vein", "Brush Creek", "Finley", and "No. 7" coal. It lies 32 to 36 feet above the Upper Freeport coal, where both seams are mined at numerous localities in Columbiana County and northern Jefferson County. The Lower Mahoning sandstone is, over extensive areas, a coarse-grained rock 15 to 30 feet thick, but is also in many places a cross-bedded, shaly sandstone or sandy shale.[1]

LOWER MAHONING SANDSTONE

Like most coal formation rocks of this character, the Lower Mahoning sandstone in Muskingum County lacks continuity; in fact shale is the prevailing rock on the horizon. In a few localities the member is a massive coarse-grained or even conglomeratic sandstone so well cemented that it forms cliffs or abrupt slopes along its outcrop.

[1]Geol. Survey Ohio, 4th Ser., Bull. 17, p. 57.

Another phase of the member is shaly sandstone, which is more or less interbedded with siliceous shale. Its stratigraphic position is at or near the base of the Conemaugh formation which begins with the covering of the Upper Freeport coal. The real basal deposit of this formation, however, is a shale all or part of which may be replaced by the Lower Mahoning sandstone. The upper limit of this member is usually the Mahoning or Thornton clay, but in a few places it merges with the Upper Mahoning sandstone, completely replacing the Mahoning coal and its associated clay.

The Lower Mahoning sandstone is conspicuous by its cliff-forming properties in Monroe and northern Highland townships. At these places it is a light-colored, coarse-grained, well-cemented sandstone, and is usually distinctly cross-bedded. The lower part of the deposit frequently contains many quartz pebbles, the largest of which are nearly one-half inch in diameter. The sandstone, in places very coarse-grained, is present in local areas in Adams, Madison, and Washington townships, but the bed is less prominent than it is in the valley of White Eyes Creek in Monroe and Highland townships. The member is a noticeable stratigraphic feature also in local areas along Salt Creek and its tributaries in Salem and Perry townships. In Wayne, Salt Creek, and Bluerock townships the horizon is more often marked by siliceous shale or shaly sandstone than by the coarse-textured material. The thickness and stratigraphy of the bed is well shown in the following record taken in Section 7, Brush Creek Township:

	Ft.	In.
Limestone, *Cambridge*	2	--
Sandstone and covered	35	--
Limestone, dark, shaly, fossiliferous, *Brush Creek*	3	--
Shale and covered	25	--
Shale	14	--
Sandstone, massive, *Lower Mahoning*	21	--
Shale, light	6	--
Coal, *Upper Freeport*	2	6

In Muskingum County the Lower Mahoning sandstone varies in character all the way from a coarse-grained, even conglomeratic sandstone to shaly sandstone, the next stage of which is siliceous shale. The color of the material changes from bluish-gray to very light-gray, depending on the quantity of argillaceous matter present. In local areas the sandstone is so well bonded that it is weather resistant, but as a general thing it is friable and disintegrates rapidly.

MAHONING LIMESTONE

The Mahoning limestone, which is from 1 to 3 feet in thickness in local areas in southeastern Ohio, is poorly represented in Muskingum County. At a few places in Harrison, Bluerock, Perry, and Salem

townships small nodules of impure limestone, bedded at the base of the Mahoning clay, mark the horizon. The material is of fresh-water origin and is non-fossiliferous.

MAHONING COAL AND THORNTON CLAY

The Mahoning coal is a rather persistent bed in the southern part of Muskingum County, but in the northern part it is seldom present, as its place is taken by sandstone. The average thickness of the bed is about 5 inches and the maximum measurement not more than 8 inches. The coal is of an inferior quality, and often tends somewhat towards the dense cannel type. The position of the bed is about 37 feet above the Upper Freeport coal and nearly 20 feet below the Brush Creek limestone. The clay, which is directly associated with the Mahoning coal, and which is known as the Thornton clay in West Virginia, where it has been utilized for ceramic purposes, averages nearly 4 feet in thickness. It is usually dark-gray in color and plastic in character. Further, in places the basal portions are ferruginous and calcareous. Two sections will be given in order to show the general stratigraphy of these members in Muskingum County.

The relation of the Mahoning coal and its associated Thornton clay to other beds of importance in Brush Creek Township is shown in the following record taken in Section 18:

	Ft.	In.
Limestone, nodular, *Cambridge*	2	--
Shale and covered	46	--
Limestone, shaly, *Brush Creek*	5	6
Clay, light	5	--
Sandstone and covered	10	--
Shale, light, siliceous	11	--
Shale, dark, fissile	6	--
Coal, *Mahoning*	--	5
Clay, dark-gray, *Thornton*	7	--
Shale and covered	25	--
Coal, *Upper Freeport*	2	--

The Mahoning coal, although thin, is rather steady in Clay and Brush Creek townships, and extends eastward into Harrison and Bluerock townships. It is regularly present along the Muskingum Valley in the western part of Bluerock Township, where it lies near the base of the hills. The associated clay is from 3 to as much as 10 feet in thickness in this area. It is plastic and somewhat siliceous in character and the basal portion in places is mottled with iron oxide pigments. The following record, taken along an abandoned road south of the Buker School in the southwestern part of Monroe Township, is representative of the thickness of the Mahoning coal and of its position with respect to other well-known beds in the northern part of the county:

	Ft.	In.
Shale, dark, with nodules of fossiliferous limestone, *Portersville*	2	--
Coal, *Anderson*	1	10

	Ft.	In.
Shale, part pink, with scattered nodules of limestone	21	--
Limestone, nodular, *Cambridge*	1	--
Shale, red, with parts covered	23	--
Shale, gray, with parts covered	28	--
Sandstone and covered, *Upper Mahoning*	23	--
Coal blossom, *Mahoning*	--	6
Clay	--	6

The Thornton clay, 2 to 5 feet in thickness, was observed at other places in this locality. In a few areas the Mahoning coal, 5 to 8 inches in thickness, is overlain by a foot or more of dark, carbonaceous shale with thin coal bands. Under these conditions the outcrop of the bed is somewhat deceptive, as it may be taken for that of a coal of fair thickness.

In Muskingum County the Mahoning coal is of interest only as a stratigraphic unit, as the bed has no practical value. The coal is hard, dense, and in places varies towards the cannel type. A little fuel has been obtained along stream beds. The associated Thornton clay is of inferior quality, as it is generally siliceous, somewhat ferruginous, and calcareous in composition. It is plastic, with fair bonding properties. The bed has not been worked for ceramic purposes in this county.

UPPER MAHONING SANDSTONE

The Upper Mahoning sandstone is not a well-marked member in Muskingum County. Its position is between the Mahoning coal and the next overlying coal which is the Mason, but which in this county is seldom present. At its best the sandstone is coarse-grained, well bonded, and massively bedded. The most common phase, however, is shaly sandstone which is thin-bedded, ripple-marked, and fine-grained. Further, it gradates on down to siliceous shales. In many places in the northern part of the county, where it is best represented, this sandstone coalesces with the Lower Mahoning sandstone into one thick bed 30 to 50 feet in thickness. At present this sandstone has no economic value worthy of consideration.

MASON COAL

The Mason coal, which is a steady bed, averaging about 1 foot in thickness in southern Ohio, is poorly defined in Muskingum County. Its position is about 14 feet above the Mahoning coal and nearly 5 feet below the Brush Creek limestone, where this member is present. In the northern part of the area its place is taken by massive sandstone or siliceous shale and in the southern part by dark, carbonaceous shale which lies below the Brush Creek limestone. The stratigraphy of the member is given in the following section taken in the southwestern corner of Section 13, Clay Township, Muskingum County, and in the northwestern corner of Section 24, York Township, Morgan County:

		Ft.	In.
Limestone, flinty, fossiliferous	*Brush Creek*	6	3
Shale, calcareous, with nodules of cherty, fossiliferous limestone	*Brush Creek*	1	1
Shale, dark		4	6
Coal, bony	*Mason*	--	4
Shale, black	*Mason*	--	1

No coal was observed on the horizon in Brush Creek, Harrison, or Bluerock townships where the Brush Creek limestone is present with some regularity. The Mason coal has no value aside from stratigraphic interest.

BRUSH CREEK LIMESTONE AND ASSOCIATED SHALES

The Brush Creek is the lowest fossiliferous limestone in the Conemaugh formation of Muskingum County. In the southern part of the area the member, although varying greatly in both structure and character, is moderately persistent, but in the northern part of the county it is absent except in one locality where the horizon is marked by dark fossiliferous shale. In its typical exposures in eastern and southern Ohio the member consists of two rather pure fossiliferous limestone beds separated by 15 to 30 feet of shale, also calcareous and fossiliferous. The upper layer of limestone is far more constant than the lower stratum and is subject to greater changes in thickness and composition. In Muskingum County only the upper bed is represented by limestone, the thickness of which varies from a few inches to as much as 10 feet, and the character of which changes from dark, carbonaceous limestone through gray flinty limestone to gray calcareous flint. Dark fossiliferous shale is a common associate of the limestone. The Brush Creek member is everywhere fossiliferous in the area under consideration. The types most abundant in the limestone are *Ambocoelia planoconvexa*, *Productus pertenuis*, *Productus cora*, and *Spirifer cameratus*. The associated shale is also rich in marine fossils which are well preserved. The average interval from the base of the Brush Creek limestone to the base of the Cambridge member is about 40 feet and to the top of the Upper Freeport coal it is nearly 57 feet. Further, it is about 20 feet above the Mahoning coal. Its position is also between the Buffalo sandstone and the Upper Mahoning sandstone, both of which are locally present in Muskingum County. Owing to one or the other of these sandstones, however, a part or all not only of the Brush Creek limestone, but also of its associated shale is replaced in many areas. This replacement is especially pronounced in the northern part of the county.

Clay Township.—The Brush Creek limestone is a rather persistent bed in Clay Township where it is present near the 950-foot contour in the southeastern part and near the 1,000-foot contour in the northwestern part. The bed varies in thickness from a few inches to as much as 10 feet. The limestone is gray in color and flinty

in character. Calcareous, fossiliferous shales are also locally present on the horizon. The limestone is rather conspicuous in sections 13 and 14 and along the ridge in sections 12 and 2.

Brush Creek Township.—In the southern part of Brush Creek Township the Brush Creek member has excellent thickness and continuity, but in the northern part of the area it is thin and fitful. The thick deposits are made up of several irregular layers of dark flinty limestone with more or less shale interstratified. Below the limestone in places dark, calcareous shale is also present. Both the limestone and shale are rich in marine fossils which are usually well preserved. The following record taken in Section 7 shows the general stratigraphy of the member:

	Ft.	In.
Limestone, *Cambridge*	2	--
Sandstone and covered	35	--
Limestone, thin-bedded, dark-gray, fossiliferous, with shaly partings, *Brush Creek*	3	--
Shale and covered	25	--
Shale, light	14	--
Sandstone, massive, *Lower Mahoning*	21	--
Shale, light	6	--
Coal, *Upper Freeport*	2	6

At other places in the southern part of this township the bed is 1 to 8 feet in thickness. The material in the thicker deposits is flinty in character. In its extension northward the bed thins rapidly and becomes wanting.

Harrison Township.—On the Brush Creek horizon in Harrison Township black fossiliferous shale is more conspicuous than limestone. The shale, however, usually contains thin beds of dark fossiliferous limestone which are not persistent either in extent or thickness. The member is rather steady in the southern part of the area, but it is seldom present in the northern part owing to its replacement by sandstone.

Bluerock Township.—The Brush Creek member is present with some regularity along the Muskingum Valley in Bluerock Township. In much of the area it is a single bed of limestone, less than 1 foot in thickness, but in a few places it is made up of two or even three such layers. Further, fossiliferous shale is a common associate of the limestone. The structure of the member is given in the following record, taken along a small stream in the central part of Section 29:

		Ft.	In.
Shale, gray, siliceous		16	--
Shale, with scattered limestone nodules	*Brush Creek*	4	6
Limestone		--	4
Shale		--	10
Limestone		--	6
Shale		--	7
Limestone		--	3
Shale, gray, soft		1	--

The limestone is of the usual dark color, and both it and the calcareous shales are very fossiliferous. It is 15 to 20 feet above the Mahoning coal and 40 to 50 feet below the Cambridge limestone. North of Gaysport only one layer of limestone was observed on the horizon.

Salt Creek Township.—The horizon of the Brush Creek limestone is above drainage along the courses of all the larger streams in Salt Creek Township, but the member is not regularly present. Local deposits, however, of either dark limestone or fossiliferous shale, or both, are found in many places. Near McDonald, in Section 34, the member is represented by 5 inches of dark fossiliferous limestone bedded in gray siliceous shale. Along the road south of the Ohio River & Western Railroad, in the western part of Section 14, the Brush Creek member consists of several thin beds of limestone interstratified with shale. Fossils are abundant in both rocks.

Perry and Wayne Townships.—The Brush Creek horizon in local areas in the southern part of Perry Township, and in the eastern part of Wayne, is marked by a bed of dark fossiliferous limestone, always less than 1 foot in thickness. In a few places a foot or two of fossiliferous shale is also present with the limestone. The position of the bed is about 40 feet below the Cambridge limestone and nearly 20 feet above the Mahoning coal.

Union Township.—The most northern exposure of the Brush Creek member observed in Muskingum County is on the A. N. Daly farm in the central part of Section 5. It consists of shales and measures 2 feet.

The Brush Creek member was not observed in Salem, Adams, Highland, or Monroe townships. Over much of these areas the place of the member is taken by sandstone, but even where shale prevails the limestone or the associated fossiliferous shale appears to be absent.

The Brush Creek member in Muskingum County is of considerable interest to the paleontologist as it is the lowest limestone of marine origin in the Conemaugh formation. Both the limestone and associated shale are highly fossiliferous and afford rich collecting. A list of the fossils so far identified may be found in Chapter V, Bulletin 17, of this Survey. The bed is so thin or the limestone so impure that it is not adapted to serve many useful purposes. The limestone in the thicker deposits of Clay and Brush Creek townships is flinty and shaly and is best fitted for road metal.

BUFFALO SANDSTONE

The normal position of the Buffalo sandstone, called the Stillwater in early reports, is between the Brush Creek and the Cambridge limestones, but in places it not only fills most of this interval but thickens, so that it replaces the Brush Creek beds and coalesces with the Upper Mahoning sandstone. Regarding this member Condit says:

It is noteworthy that the Buffalo sandstone in the coarse, massive form is everywhere very localized, often being found in one hill, and sandy shale on the same horizon near by. Also it has been observed that in the areas where the massive coarse-grained Buffalo is prominent, the underlying beds to the base of the Conemaugh are likely to show a similar coarse-grained texture; whereas in other localities, sandy shales occupy most of the section. In other words, there seems to have been a localized deposition of coarse sands during much of the earlier part of the Conemaugh time. This persistent piling up of coarse sediments in almost continuous beds a hundred or more feet thick, interrupted only by thin clays or maybe impure conglomeratic limestones, while thick shale beds were contemporaneously forming in other areas, suggests delta formation. Further evidence in support of this view is the general coincidence in direction of slope of the bedding planes in any limited area.[1]

Although sandstone occurs with considerable regularity on the Buffalo horizon in Muskingum County, the bed for the most part is thin, broken, or shaly. In local areas, however, in the northeastern part of the county, it has the coarse-grained, massive character, so conspicuous in other parts of Ohio. As the member has so little value economically it will be briefly treated.

The general stratigraphy and character of the member in the southern part of the county is shown by the following composite section, taken along Cedar Run in sections 31 and 32, Harrison Township:

		Ft.	In.
Limestone, nodular, *Cambridge*		1	--
Shale and covered		5	--
Sandstone, shaly, *Buffalo*		15	--
Shales, siliceous		15	--
Covered		5	--
Limestone, dark, fossiliferous	*Brush Creek*	--	8
Shale, dark, fossiliferous		3	4
Shale, dark		12	--

Shaly sandstone is the usual phase of the Buffalo member in Clay, Brush Creek, Harrison, Bluerock, and Salt Creek townships, but in its extension northward into Perry, Union, Salem, Highland, and Monroe townships, coarse-grained sandstone is a common feature on the horizon. The following record, taken on the farm of C. W. Welker, in Section 19, Monroe Township, is about representative of the member in the northern part of the county:

	Ft.	In.
Limestone, nodular, *Cambridge*	1	--
Clay, shale, and covered	16	--
Sandstone, coarse-grained, with parts covered, *Buffalo*	30	--
Sandstone, massive, coarse-grained, lower part conglomeratic, *Upper* and *Lower Mahoning*	44	6
Disconformity.		
Shale	16	--
Coal and parting, *Upper Freeport*	6	7

The Buffalo sandstone is not put to any useful purpose in Mus-

[1]Geol. Survey Ohio, 4th Ser., Bull. 17, pp. 48-49.

kingum County. At its best it is a friable, coarse-grained, micaceous rock of a light-gray color, and is bonded chiefly by argillaceous matter and iron oxides. Owing to the rapidity with which it disintegrates on exposure to weathering agencies, it has no value for building stone. Possible uses are molding sand for the medium-textured material, and abrasive sand for sand-blasting for the coarse-grained rock.

WILGUS COAL

The position of the Wilgus coal is either directly or only a few feet below the Cambridge limestone. The horizon is poorly marked in this county, for only in a few places was even a soot streak or a thin bed of impure coal observed. The most conspicuous outcrop of this coal found in the county was exposed at the crossroads on the ridge in the extreme southwestern part of Monroe Township, where the coal appears to be shaly in character and has no value. The record obtained at this place is given below:

	Ft.	In.
Coal blossom, *Anderson*	1	6
Shale and covered	35	--
Limestone, ferruginous, fossiliferous, *Cambridge*	--	8
Coal blossom, *Wilgus*	1	6
Clay	2	--

CAMBRIDGE LIMESTONE

The Cambridge limestone named by Prof. E. B. Andrews from exposures near Cambridge, Guernsey County, is of wide extent in Ohio as it extends from Jefferson and Columbiana counties on the east to Lawrence County on the south. Along this belt, however, many wants occur over large areas and many variations are noticed in both the thickness of the bed and in the character of the material. It changes from a persistent, uniformly-bedded limestone in southern Ohio to a nodular, fitful, and inconstant stratum in central and eastern Ohio. In composition it changes from a rather pure limestone of a dark-gray color to cherty limestone of a yellowish tint or to a porous ferruginous material of a rusty appearance. In places calcareous, fossiliferous shale is also associated with the limestone. The Cambridge member is everywhere fossiliferous and is the second well-defined marine limestone in ascending order in the Conemaugh formation of Ohio. The total number of species of this ancient fauna is rather large, but the number present in the bed at any given place is usually small. Forms abundant in the rock in one locality may be nearly absent in deposits not far distant. Persons interested in the fauna of the Cambridge limestone will find the subject well treated in Chapter V, Bulletin 17, of this Survey.

In Muskingum County the position of the Cambridge limestone is, on the average, nearly 40 feet above the base of the Brush Creek and 108 feet below that of the Ames limestone. The Cambridge

limestone with few exceptions is more or less nodular in character, although the bed may be several feet in thickness. In places in the southern part of the county the horizon is marked only by marly limestone in clay. The member is subject not only to sudden changes in thickness, but also to erratic changes in its distance from other important members. These changes are due in part at least to the unevenness of the floor upon which the member was deposited. Further, in local areas it has suffered from later erosion. The limestone is bedded in shale which in places is clay-like in character and light or mottled in color. The Cambridge member is present above drainage in Clay, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Rich Hill, Perry, Union, Salem, Highland, Adams, and Monroe townships. In some of these townships, however, the areas are small as the bed lies either near the summits of the high ridges or so near drainage level that the dip of the strata causes it to pass below cover in a few miles. The member will be treated rather briefly.

In Clay Township nodular Cambridge limestone is present in local areas on the high ridges in the eastern part. The deposits in Brush Creek Township are usually rather local in extent, but are so spaced that the horizon may be followed with ease. The variation in structure is from nodular limestone in light clay to well-stratified beds 2 to 4 feet in thickness. The limestone in places is flinty and ferruginous, resembling the Brush Creek member; or is light-gray and rather pure, resembling the Ames, both of which are also present in the area.

Although the Cambridge limestone lacks continuity in Harrison Township many scattered deposits are present especially in the southern part. The bed is due in all of the township except the extreme northern part. In places the bed has fair thickness, but the limestone is not of high quality. The material has been but little utilized even for minor purposes. In Bluerock Township the horizon of the Cambridge limestone is above drainage along the Muskingum River and along Manns Fork of Salt Creek, in sections 3, 4, and 10. The bed is very unsteady and the limestone nodular in character. The thickness of the deposits varies from a few inches to as much as 4 feet.

In the western part of Salt Creek Township the horizon of the Cambridge limestone lies not far below the summits of the main ridges, but, owing to the dip of the strata, in the eastern part, it lies near drainage level. The deposits are patchy and the material is of the usual nodular character. A few deposits of Cambridge limestone are present along the high ridges in the southeastern part of Wayne Township. Its position is 80 to 95 feet above the Upper Freeport coal. The bed is thin and the material impure. But little needs be said regarding the Cambridge limestone in Rich Hill Township as the member is above drainage only along the streams in sections 6, 7, 18, 19, and 20. Owing to the depth of covering along the valleys few exposures

were observed and these show no new features. In a general way the Cambridge limestone is present along the ridges in the eastern half of Perry Township. In this area the bed is not only thicker, but it is more persistent than it is in the townships to the south. The usual thickness of the member is between 2 and 4 feet.

In Union Township the Cambridge limestone is above drainage along the courses of all the larger streams in the northern part and along the headwaters of White Eyes Creek, in sections 24 and 25 in the southern part. The Cambridge member has its maximum development in this county, in the vicinity of New Concord, where the deposits are from 3 to as much as 12 feet in thickness. Along the headwaters of Salt Creek in the western part the bed rarely reaches 5 feet in thickness and the usual measurement is 1 to 3 feet. The lack of uniformity in the conditions under which the member was deposited in the shallow Conemaugh sea is well defined in this township. The deposits vary from marly limestone in clay through large nodules of limestone closely packed to massive beds of limestone, the thickness of which changes rapidly owing to the unevenness of the upper surface. Moreover, the composition of the material as well as the abundance of fossils and the types of life change noticeably from place to place. A composite section taken just east of New Concord is given below:

	Ft.
Limestone, *Ames*	1
Covered	7
Sandstone, soft	30
Shale and covered	37
Coal blossom, *Anderson*	1
Clay and covered	10
Limestone, flinty, siliceous, fossiliferous, *Cambridge*	12
Clay, hard, with nodules of limestone	5
Shale	3

Other deposits west and south of New Concord measure from 3 to 8 feet in thickness. The limestone has been used in a small way for road metal, concrete stone, and foundation material. In the northwestern part of the township the average thickness of the bed is about 2 feet.

The Cambridge limestone is present along the ridges in all of Salem Township, except the extreme western part. The deposits are somewhat local and the limestone decidedly nodular. Near Adamsville the member lies close to the 1,000-foot contour, and in the southeastern corner of the township about 900 feet above tide. The horizon of the Cambridge member is above drainage along the headwaters of North Crooked Creek in the southern part of Highland Township, and along the courses well towards the headwaters of the tributaries of White Eyes Creek in the northern part. The bed is persistent, but varies greatly in thickness and in composition. The most massive deposits

are along Pleasant Valley south of Bloomfield. A sample was taken for chemical analysis from a deposit outcropping along the stream in Section 21. The thickness of the bed at this place is 8 feet 6 inches. In this locality small quantities of this limestone have been used for road building. In the northern part of the township the average thickness of the bed is about 2 feet, and the maximum measurement obtained is 5 feet.

The areas of Cambridge limestone in Adams Township are small as the bed lies near the summits of the main ridges. The deposits vary from 1 to 4 feet in thickness. The most northern exposure observed was along the road in quarter Section 18, which is in the northwestern part of the area, about 2 miles south of Wills Creek. The elevation of the bed in this locality is about 1,060 feet above tide. In the southern part of the township the deposits are thin, and in places consist of marly limestone in clay. The usual representative of the Cambridge member in Monroe Township is nodular limestone in clay, the thickness of which is seldom more than 2 feet. The deposits, however, are rather continuous, and are found on the main ridges in the southern and in the western parts of the area.

Economic Value

Aside from deposits in local areas the Cambridge member is so thin or broken that it is a resource of little value to Muskingum County, except for its contribution of mineral salts for soil enrichment along its outcrop. The effect of the limestone disseminated by solution through the clay soils along the horizon is shown by the growth of clovers and blue grass. The member attracts most attention in the vicinity of New Concord, where the deposits measure from 3 to as much as 12 feet in thickness. The character of the limestone in this region is shown by the following analysis, made by Prof. D. J. Demorest, of a sample taken by R. E. Lamborn, in 1917:

Silica, SiO_2	33.75
Alumina, Al_2O_3	4.01
Ferric oxide, Fe_2O_3	2.23
Titanic oxide, TiO_2	.22
Lime, CaO	31.61
Magnesia, MgO	.78
Phosphorus, P	.055
Sulphur, S	.079

Converting this into its mineral analysis the results are approximately as follows:

Clay, $Al_2O_3.2SiO_2\ 2H_2O$	10.15
Quartz, SiO_2	29.03
Pyrite, FeS_2	.15
Limonite, $2Fe_2O_3.3H_2O$	2.49

Rutile, TiO_2	.22
Calcium phosphate, $3CaO.P_2O_5$	.28
Calcium carbonate, $CaO.CO_2$	56.18
Magnesium carbonate, $MgO.CO_2$	1.64
Total	100.14

The above analysis shows a very siliceous limestone in which the iron-bearing minerals are also high. This condition prevails not only in the deposits present in the vicinity of New Concord, but also in those found elsewhere in the county. On calcination, such a limestone, owing to the formation of silicate minerals, gives a dense product which has but little slaking power. The iron oxide is also sufficiently high to impart a dark-gray color to the material. For agricultural purposes the Cambridge limestone, when compared on the basis of the lime and magnesia contents, has only about half the value of the commercial limestones of northern and western Ohio. In areas where the material is readily available along outcrop exposures, and where it may be ground at a low cost owing to cheapness of fuel and labor, or in outlying districts where freight and haulage are the chief items of expense, the Cambridge limestone may be used in the raw state with good economy. The portable crushers or pulverizers used in many places give a satisfactory product. This limestone has no value for metallurgical purposes or for Portland cement. Its chief use is for road construction. The unweathered limestone is hard and tough. Its crushing strength and abrasive values are high, but its cementing power is rather low. This limestone has been used in the construction of parts of the National Road, and is pronounced by the engineers to be satisfactory. In local areas the supply of Cambridge limestone, readily available, is amply sufficient to build all the roads in the locality. The material properly ground and graded makes a good body for concrete, but in this county it is not as cheap a filler as gravel, which is marketed in a large way from deposits along the Muskingum River.

BLOOMFIELD LIMESTONE

A rather persistent bed of limestone is present in Highland and Salem townships, and local deposits were observed along the horizon as far south as Harrison and Bluerock townships. Owing to the fact that the stratum has excellent thickness and regularity west of Bloomfield in Highland Township it is called the Bloomfield limestone in this bulletin. On the average its position is about 11 feet above the base of the Cambridge limestone and nearly 5 feet below that of the Anderson coal. These intervals, however, are subject to considerable variation. From all the measurements secured the mean thickness of the Bloomfield member is 1 foot 5 inches and the maximum 2 feet 6 inches. The color of the limestone is uniformly light-gray, except in some of the thin deposits, where it is stained with iron oxide. The rock is hard and dense

and is not easily disintegrated by weathering agencies. The Bloomfield limestone is not fossil-bearing, which readily distinguishes it from the underlying Cambridge member. It is of fresh-water origin and is probably confined to only a small area in Ohio. Deposits were observed in Monroe, Highland, Salem, Perry, Salt Creek, Bluerock, Harrison, and Brush Creek townships, but the member will be traced only in a general way. The most massive deposit of Bloomfield limestone observed in Muskingum County is along the small stream in the southern part of Section 9, Highland Township. The type record which follows was taken along the road near-by:

	Ft.	In.
Coal blossom, *Anderson*	1	--
Clay and covered	6	--
Limestone, gray, massive, blocky, non-fossiliferous, *Bloomfield*	2	6
Shale and covered	13	6
Limestone, nodular, fossiliferous, gray, *Cambridge*	3	--

ANDERSON COAL

The Anderson, formerly called the Norwich, is by far the most conspicuous coal bed in the Conemaugh formation of Muskingum County, as it is very steady in both thickness and extent. It is wanting in but few places and there only for short distances. The thickness of the bed is seldom less than 1 foot 4 inches or more than 2 feet 6 inches. The average measurement from all the records obtained is 1 foot 11 inches. In many places the bed contains at a little distance above the middle a thin layer of bony coal or carbonaceous shale the thickness of which varies from $\frac{1}{4}$ inch to 2 inches. The Anderson coal is with few exceptions overlain by the dark carbonaceous and fossiliferous shale and limestone of the Portersville member and is underlain by a few feet of light-colored, siliceous and calcareous clay. This coal lies, on the average, about 5 feet above the unsteady Bloomfield limestone. Owing to the wide extent of the Anderson coal and to the prominence of its outcrops along roads and streams, it is an important bench for the stratigrapher. The member is present above drainage in Clay, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Rich Hill, Perry, Union, Salem, Highland, Adams, and Monroe townships. Owing to the general dip of the rocks to the east and south, the areas of coal in some of these townships are small.

The Anderson coal is confined to the high ridges and knobs in the eastern and southern parts of Clay Township. The bed is very steady and on the average is about 1 foot 8 inches in thickness. Persistency in both thickness and extent is the general feature of this coal in Brush Creek Township, where the member extends along the ridges in the southern and eastern parts. The coal is not mined even for local use; hence the only measurements obtained were along road cuts and stream beds. These exposures, however, indicate that the usual thickness of the coal is from 1 foot 4 inches to 2 feet 6 inches.

The Anderson coal is present in practically all of Harrison Township. The member is very persistent except in local areas where it is replaced by the massive Cow Run sandstone. This coal at the abandoned quarries on Cedar Run, in Section 31, was sampled for chemical analysis. The record taken at this place follows:

		Ft.	In.
Sandstone, *Cow Run*		22	--
Shale, with irregular layers of ferruginous limestone	*Portersville*	--	8
Shale, dark, extremely fossiliferous	*Portersville*	1	7
Coal, *Anderson*		1	8
Clay		1	--

This coal is mined by drifting in a small way for domestic use near the head of Back Run in Section 30. Along the ridges north of this small quantities of fuel are also obtained by stripping.

The Anderson coal, which is above drainage along all the streams in the western and northern parts of Bluerock Township, contributes considerable fuel for local needs. It is mined both by drifting and by stripping. The horizon is always marked not only by coal, but also by the overlying dark shale and limestone of the Portersville member, except where these rocks were removed by the erosive agencies that preceded the deposition of the Cow Run sandstone. The most of the workings are in the vicinity of Coal Hollow, in Section 27, where the member passes below drainage. The usual thickness of the coal is about 2 feet and the maximum measurement nearly 2 feet 6 inches. Small mines are also operated in Section 16, where the following record was obtained on the property of John Daw:

		Ft.	In.
Shale, calcareous, with nodules of limestone, *Portersville*		1	--
Coal	*Anderson*	--	11
Shale	*Anderson*	--	¼
Coal	*Anderson*	1	5

No mine measurements of the bed were obtained along the Muskingum River in the northern part of the township, but the outcrop appearance indicates that the coal is about 2 feet in thickness, and is very steady.

The Anderson coal is above drainage in all of Salt Creek Township, although it lies close to drainage level along the courses of the streams in the eastern part. It furnishes some fuel at present for local needs. At the mine of George Wokey, which is located in the southern part of Section 11, a sample was taken for chemical analysis. The structure and thickness of the coal are given below:

		Ft.	In.
Shale		6	--
Coal	*Anderson*	--	7
Shale	*Anderson*	--	¼
Coal	*Anderson*	1	5
Clay, siliceous		2	--

Along Kent Run the Anderson coal is about 2 feet in thickness and has been mined in a few places. The outcrop conditions indicate that the coal, in Salt Creek Township, is very steady and is about 2 feet in thickness, especially along White Eyes Creek and its tributaries west of Le Fevers Ford and along Williams Fork northeast of Chandlersville. The areas of Anderson coal in Wayne Township are small as they are confined to the high ridges and knobs in sections 19, 29, and 32. The elevation of the bed is about 900 feet above tide.

In Rich Hill Township the areas of Anderson coal are confined to the valley of White Eyes Creek in Section 6, to that of Williams Fork in sections 7 and 8, and to that of Buffalo Fork in sections 18, 19, and 20. Along these streams a few small mines are operated by the farmers for domestic coal. In Section 19 the Cow Run sandstone replaces a part or all of the Portersville member and forms the real roof of the Anderson coal. The general stratigraphy of the member in the northwestern part of the township is given in the following record taken along the south bank of White Eyes Creek, in the north central part of Section 6:

	Ft.	In.
Sandstone, shaly, *Cow Run*	8	--
Shale, gray	1	--
Shale, carbonaceous, *Portersville*	4	--
Coal, *Anderson*	2	3
Clay and covered	4	--

In a general way the Anderson coal is confined to the ridges and knobs in the eastern half of Perry Township. The elevation of the bed on the hill south of Shuck School, in Section 9, is about 930 feet, and along the stream near the Pleasant Valley School, in Section 21, about 840 feet. The coal is above drainage along the courses of all the larger streams in the northern part of Union Township, and along the lower courses of the headwaters of White Eyes Creek in the southwestern part. The bed is steady in both thickness and in extent, and for a thin stratum has conditions favorable for mining. Near Norwich both the Anderson and Harlem coals have been mined in a small way by stripping and drifting.

Small areas of Anderson coal are present on the high ridges and knobs in the eastern half of Salem Township. Owing to the anticline that extends across Highland Township the Anderson coal is above drainage in the entire area. Along the small stream in the central parts of sections 20 and 21 many small mines have been operated. In this locality the coal is mined by drifting, and in places it is directly overlain by the Cow Run sandstone. The Anderson coal is present only on the high ridges and knobs in the southeastern part of Adams Township, and it is also found in Monroe Township, where it is present along the ridges in the western and southern parts.

Economic Value

The Anderson is by far the most important coal in the Conemaugh formation of Muskingum County as it is of wide extent, of remarkable uniformity in thickness, and of fair quality, and for a thin bed has conditions very favorable for successful mining in a small way. The area of coal above drainage is approximately 125 square miles, from which not more than 25 square miles should be deducted for the areas of rotten coal along the outcrop and under thin covering, and for the parts exhausted by mining. As previously stated, the mean thickness of the coal from the average of all the measurements taken under favorable conditions, and which were well distributed across the county, is 1 foot 11 inches. The total quantity of fuel in such a bed is about 3,450 tons per acre, of which at least 70 per cent or 2,415 tons should be secured in mining. This amounts to 1,545,600 tons per square mile, or to 154,560,000 tons for the 100 square miles of workable coal in the county.

In the small country mines in this area but little posting is required except near the outcrop, where the shales are somewhat tender, owing to weathering. The floor of the coal is a hard siliceous clay which is well able to withstand the weight of the overburden without squeezing where the proper areas of pillars are left. Owing to the protecting influence of the hard carbonaceous shales overlying the bed the coal is solid and firm close to the outcrop. This condition is favorable not only for drift mining, but for stripping. The general character of the fuel is shown by the analyses that follow.

The Anderson coal was sampled by R. E. Lamborn and the writer at the abandoned quarries on Cedar Run, in the southern part of Harrison Township. The sample was cut from the coal in a bench mine, but is considered representative, as the coal was bright and solid and had about its natural moisture. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	63.61	Moisture	5.66
Hydrogen	5.30	Volatile matter	42.72
Oxygen	13.48	Fixed carbon	39.92
Nitrogen	1.03	Ash	11.70
Sulphur	4.88		
Ash	11.70		

Calorific value { 6,579 calories. / 11,842 B. t. u.

Air drying loss of moisture, 2.7 per cent.

Fusion temperature of ash { incipient, 1,101° C. / complete, 1,204° C.

At the mine of George Wokey north of Chandlersville, in Salt Creek Township, the Anderson coal was sampled for chemical analysis

by R. E. Lamborn and the writer. The sample was cut under good conditions, as the mine was dry and the coal bright and solid. Prof. D. J. Demorest analyzed the sample.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	68.90	Moisture	6.61
Hydrogen	5.61	Volatile matter	39.84
Oxygen	13.50	Fixed carbon	44.96
Nitrogen	1.32	Ash	8.59
Sulphur	2.08		
Ash	8.59		

Calorific value { 6,854 calories. / 12,337 B. t. u.

Air drying loss of moisture, 3.3 per cent.

The following analyses of the Anderson coal, which was formerly known as the Norwich bed, and which was sampled in the vicinity of Bloomfield in Highland Township, are copied from Volume III, page 257, of this Survey:

Specific gravity	1.305	1.314
Moisture	2.90	3.20
Volatile matter	34.70	33.00
Fixed carbon	57.80	56.40
Ash	4.60	7.40
Total	100.00	100.00
Sulphur	2.60	2.96
Fixed gas per pound, in cubic feet	3.72	3.40
Color of ash	Light-gray.	Reddish.

The above analyses show that the Anderson coal is of somewhat inferior quality as the ash and sulphur are rather high and as the heating value is moderately low. The ash is usually reddish-gray in color and is not especially troublesome from clinkering. The sulphur occurs in both the form of ferric sulphide and of complex organic sulphides. The coal burns rather freely, but with a sooty flame. It belongs to the coking type of coals, but the product formed is hard and dense.

PORTERSVILLE MEMBER

Regarding this member Condit states:[1]

From 12 to 30 feet above the Cambridge limestone is another fossiliferous horizon which is seldom more than a calcareous or pyritous shale, forming the roof of the Anderson coal. The name Portersville is chosen for this bed from the village of that name near the eastern edge of Perry County.

In Muskingum County the mean thickness of the Portersville bed from many measurements is 4 feet 9 inches and the maximum thick-

[1]Geol. Survey Ohio, 4th Ser., Bull. 17, pp. 41-42.

ness observed is 10 feet. Owing to the lack of deposition and to the effect of erosion that preceded the laying down of the Cow Run sandstone, the member in a few localities is wanting. In most of the area the Portersville member is the real roof of the Anderson coal, but in parts of Bluerock and Salt Creek townships it is separated from the coal by a few feet of blue non-fossiliferous shale. The main body of the member is composed of dark, somewhat fissile shale, which is carbonaceous and calcareous in composition and is extremely fossiliferous. Nodular limestone either deposited in somewhat regular beds or distributed erratically throughout the shale are present in most exposures. These nodules vary in size from ¼ inch to as much as 1 foot and in color from light-gray to nearly black.

This limestone as well as the shale is rich in remains of marine life. The fossils in the shale commonly have pyritized shells and are well preserved; whereas those in the limestone have the original calcareous shells and have all the delicate markings minutely traced. The fossils in the limestone are of special interest as they are very small and represent a wide range in the types of life that flourished in the ancient Conemaugh sea.[1] The Portersville member is present above drainage in Clay, Brush Creek, Harrison, Bluerock, Wayne, Salt Creek, Rich Hill, Perry, Union, Salem, Highland, Adams, and Monroe townships.

COW RUN SANDSTONE

The rugged but picturesque topography along the Muskingum River, in the southern part of Muskingum County, is due in a large measure to the outcropping of the massive Cow Run sandstone, that forms many projecting cliffs and steep bluffs, along which are strewn great blocks of the resistant material. Regarding this member Condit says:[2]

> This name, although not very euphonious, seems appropriate since it is in general use among the oil drillers of Ohio and West Virginia. It must be remembered, however, that the name Cow Run is applied by them to almost any shallow sand; hence is rather indefinite.

The average thickness of the bed is about 20 feet, but measurements of 25 to 30 feet are not uncommon. The sandstone is seldom broken by regular partings or by interbedded shales. It takes the place of the lower part of the thick body of shales that lie between the Anderson and Barton coals. The disconformity at the base of the member is usually well defined, but the erosion period was evidently of no great length and the action confined to comparatively small areas. The Cow Run is a coarse-grained sandstone, the basal portion of which is frequently somewhat conglomeratic. This member is

[1] Geol. Survey Ohio, 4th Ser., Bull. 17, Chapter V.
[2] Geol. Survey Ohio, 4th Ser., Bull. 17, p. 39.

very prominent in Harrison and Bluerock townships and it is represented also in Brush Creek, Salt Creek, Wayne, Union, Salem, and Highland townships.

Economic Value

The Cow Run sandstone was formerly quarried rather extensively in Harrison Township and was shipped by both rail and river to outside markets, as well as to points within the county. The member is of equal value in Bluerock Township, but it has been worked only to supply the local needs of the farmers. Aside from these areas the deposits in Muskingum County are of little value as a source of building stone. The Cow Run is coarser grained than the average coal formation sandstone and the basal portion in places is conglomeratic in character. At its best the material is well cemented and weather resistant. The sand grains are largely quartz and are well rounded. Mica, feldspar, magnetite, garnet, etc., form a small percentage of the mass. As the member is but little broken by shale partings or bedding planes, the material may be quarried in almost any size of blocks desired. Although the rock is somewhat cross-bedded it gives no serious trouble by parting along these lines. The chief purposes for which the Cow Run sandstone was utilized were canal locks, bridge piers and abutments, road culverts, building foundations, and retaining walls. It was used to some extent also for flagstone for steps, walls, caps and sills of buildings, for chimneys and fireplaces, and for many minor purposes. At present owing to the extensive use of Portland cement the Cow Run sandstone is but little employed for useful purposes even in the areas in which it is well developed.

EWING LIMESTONE

The Ewing member in Muskingum County needs only passing mention as the bed is present in but few places. The best deposits are in Harrison and Bluerock townships. From the exposures observed its position is about 6 feet below the Barton coal, also poorly represented, and about 40 feet above the Anderson coal. The deposits consist of ferruginous nodules of limestone which are either irregularly distributed in clay or shale or are deposited in clay in one or more rather definite layers. Some fossils which are presumably of fresh-water origin are present in the material.

BARTON COAL

The Barton is the middle one of the three coals that lie between the Cambridge and Ames limestones. In Muskingum County its mean position is 45 feet below the Ames limestone, and 62 feet above the Cambridge limestone. The member lacks continuity, but scattered deposits are present over the area. In composition it varies from a dense bituminous coal to black carbonaceous shale or to some mixture of these rocks. The average thickness of the bed is not more than 6

inches and the maximum measurement does not exceed 1 foot 4 inches. The most prominent outcrops observed were in Harrison, Bluerock, Salt Creek, and Highland townships.

Along Cedar Run, in the southern part of Harrison Township, the Barton coal is about 6 inches in thickness, and is overlain by siliceous shales which contain many well-preserved plant fossils. In the northern part of Section 28, Bluerock Township, the horizon of the coal is marked by 2 feet of black carbonaceous shale with thin coal bands. Shaly coal about 1 foot in thickness is present along Kent Run in the southern part of Salt Creek Township. In Muskingum County this member has no value, even for a local supply of fuel, as the bed is thin and the coal impure.

SALTZBURG SANDSTONE

In Muskingum County shale is the prevailing rock in the interval between the Barton and Harlem coals, but in local areas this is partially replaced by sandstone. The position of these sandstone deposits is somewhat erratic, but the horizon along which they occur the most frequently is near the base of the interval or above the Barton coal. A heavy sandstone which occurs on this horizon, and which reaches a thickness of 100 feet near Saltzburg, Pennsylvania, has been named by Dr. J. J. Stevenson the Saltzburg.

In the area under consideration for this bulletin the member is represented by soft friable sandstone, which is usually shaly in character and considerably cross-bedded. The massive deposits are rather coarse-grained, but are seldom so well cemented as to form prominent outcrops. The thickness of the bed varies from a few feet to as much as 40 feet, but the average measurement is less than 10 feet.

In the northern part of Bluerock Township and in the southern part of Salt Creek the Saltzburg member is rather persistent, but it varies greatly in thickness and character. Local deposits are also present east of Norwich, in Union Township, and south of Bloomfield in Highland. Economically the Saltzburg sandstone is of little value in Muskingum County.

ROUND KNOB SHALE

In Muskingum County the usual position of the Round Knob shale, or the Pittsburgh red shale of the Pennsylvania and West Virginia surveys, is in the upper part of the interval between the Harlem and Barton coals. These limits, however, are variable, as in places the top of the bed is just below the Ames limestone and the base considerably below the horizon of the Barton coal. In its typical exposures the member is made up of beds of red and brown shale and clay shale, in which thin layers of blue shale and shaly sandstone are often interstratified. Ripple marks are common in the thin sandstones, which also may be colored with iron oxide. Nodules of limestone and hema-

tite are usually plentiful, especially in the soft argillaceous shale. Stratification planes are very prominent in the more siliceous strata, but they are scarcely discernible in the soft clay-like beds which, however, make up only a small part of the deposits. Owing to the plastic impervious nature of the material the outcrop of the member is marked by a spring line along which land slips are very conspicuous. Regarding the color of the beds Condit says:[1]

> There has been much dispute as to the cause of the red color on the "Coal Measure" beds. That it is in the case of the Round Knob horizon original rather than a secondary phenomenon due to the reaction of weathering, is evident, since the redness is persistent where the beds are hundreds of feet below the surface, as is shown by oil drillers. Such colors are entirely wanting in the lower beds of the Pennsylvanian series; and appear near the middle of the Conemaugh for the first time. It is true that reddish tints are seen at a few horizons in the lower third of the formation, but these are largely secondary, or in other words, the result of weathering, and only appear at or near the outcrop. It is probable that the changes in climate together with varied sources of supply of the sediments are largely responsible for the red beds.

The Round Knob member is not a conspicuous stratigraphic unit in the geological column of Muskingum County, as in most of the area its place is taken by gray siliceous shale or shaly sandstone. Local deposits, however, are present in Clay, Brush Creek, Harrison, Bluerock, Salt Creek, Rich Hill, Perry, Union, Salem, and Highland townships. The following record, taken along the road in the southwestern part of Section 9, Highland Township, shows the general position of the member:

	Ft.	In.
Limestone, *Ames*	--	10
Shale, gray, with parts covered	19	2
Coal blossom, *Harlem*	1	--
Clay shale, red, parts covered, *Round Knob*	22	--
Shale, soft, drab	13	--
Shale, gray, and sandstone, shaly	55	--
Shale, dark, *Portersville* horizon	4	--
Coal blossom, *Anderson*	1	--

In parts of Harrison and Bluerock townships a rather persistent bed of limestone appears near the base of the Round Knob member, and it is often present even where the place of the red shale is taken by gray siliceous shale and shaly sandstone. The limestone is light-colored, non-fossiliferous, and has a blocky or somewhat nodular structure. The pure non-fossiliferous character of this limestone distinguishes it from the ferruginous, fossiliferous deposits of the underlying Ewing member, which are occasionally present in the same locality. The greatest thickness of the bed observed is about 2 feet, but the average measurement is only about 1 foot.

The Round Knob shale is unsuited for ceramic products as the

[1]Geol. Survey Ohio, 4th Ser., Bull. 17, p. 36.

plasticity is high, the drying properties poor, the shrinkage excessive, and the burned body brittle. Owing to the content of lime, blue grass thrives on these red clay soils, which are therefore valuable for stock raising.

HARLEM COAL

Next to the Anderson the Harlem is the most important coal member in the Conemaugh formation of Muskingum County, as the bed extends with but few wants across the area, and in places has sufficient thickness for drift mining. The position of the Harlem coal is best referred to the Ames limestone as a stratigraphic bench, below which it lies on the average about 19 feet. The extremes of the intervals observed are 11 feet and 33 feet. The average thickness of the bed from a number of measurements taken across the county is 1 foot 5 inches, and the maximum height not more than 2 feet 6 inches. In most of the field the Harlem member consists of only one coal bench, but in local areas it is broken into two layers with a few inches of clay or shale as the parting material. The upper stratum of coal is generally thin and in places impure. The coal is usually overlain by a foot or two of dark carbonaceous shale, and underlain by about the same thickness of light siliceous clay. The Harlem member is present in Clay, Brush Creek, Harrison, Bluerock, Meigs, Wayne, Salt Creek, Rich Hill, Perry, Union, Salem, and Highland townships, but the areas of coal in some of these are very small.

The deposits of Harlem coal are confined to the high ridges in the eastern part of Clay Township and to those in the southern and eastern parts of Brush Creek. The outcrop exposures along the roads and gullies indicate that the thickness of the bed varies from 1 foot to 1 foot 6 inches. In Harrison Township the coal was observed as far north as Butterbean Ridge in the central part of the township. Although persistent, the bed is everywhere thin and has not been utilized as a source of fuel, except along stream beds where the covering is shallow. The following record taken near the head of Cedar Run, in Section 31, is about representative of the thickness and structure of the member in the southern part of the township:

		Ft.	In.
Shale, gray to dark		13	8
Coal	*Harlem*	--	5
Shale, carbonaceous	*Harlem*	--	1
Coal	*Harlem*	1	--
Clay shale		3	--

In Bluerock Township the Harlem coal is present along all the small streams flowing westward into the Muskingum River and along Manns Fork of Salt Creek as far south as Section 14. Although subject to but few wants, the bed is changeable in both character and structure. Along the stream, in the central part of Section 33, the coal measures 1 foot 9 inches and is broken by 5 inches of shale. Some

fuel has been obtained by stripping along the outcrop at this place. Along the stream in the northwestern part of this section the good coal is only 9 inches in thickness. In Section 28, well-preserved plant fossils are abundant in the roof shale of the Harlem coal, which measures 1 foot 9 inches. North of Gaysport, in parts of sections 21 and 16, the place of the coal is taken by a black fissile shale, which has a thickness of more than 1 foot and lies, on the average, about 20 feet below the Ames limestone. The coal thickens again in local areas along Manns Fork of Salt Creek.

The only area in which the Harlem coal is present above drainage in Meigs Township is along Meigs Creek from the vicinity of Museville to the Muskingum-Morgan county line. The coal lies not far above the stream bed and in parts of the area it is thin or wanting. The most prominent exposures observed were north of Museville, where the stratum is about 1 foot 6 inches in thickness and lies nearly 16 feet below the Ames limestone. The areas of this coal in Wayne Township are confined to the high knobs along the ridge in Section 32. In Salt Creek Township the coal is present in sections 1, 8, 25, and 35. The horizon is well marked across the area except in a few localities where the coal is replaced by sandstone.

The Harlem coal is present along the courses of all the larger streams in the western half of Rich Hill Township, but the bed is generally thin and in places it is wanting. In local areas the weathered coal along the outcrop is about 2 feet in thickness, but a part of the bed is somewhat bony. In Perry Township this coal is confined to the high ridges in the area east of Salt Creek and south of the Baltimore & Ohio Railroad.

In Muskingum County this coal is at its best in the vicinity of Norwich, where it was formerly mined in a small way by drifting. Although the bed is persistent, it is subject to considerable variation in both thickness and quality. The mines just north of Norwich had so fallen that no good section of the coal was obtained, but the bed is stated to be about 2 feet 8 inches in thickness. The coal was also mined in a small way south of Sundale in Section 14, near the summit of the Baltimore & Ohio Railroad in Section 8, and in the southeastern part of Section 5. Small quantities of fuel have also been mined from this bed in the vicinity of New Concord.

But little needs be said regarding the Harlem coal in Salem Township as the bed is confined to the high ridges and knobs in the eastern tier of sections. This coal is regularly present in all of Highland Township except in some of the extreme northern sections. Owing to the anticline that crosses the area the bed which lies near the summits of the ridges in the western part also retains this position in the eastern

part. Along the outcrop the measurements of the coal in this township vary from 1 foot to 1 foot 8 inches. It is in one bench and appears to be of fair quality. No drift mines were observed.

Economic Value

The Harlem coal adds but little to the fuel resources of Muskingum County, as the average thickness of the bed from a number of measurements taken under favorable conditions and in several townships is about 1 foot 5 inches and as the maximum thickness is not more than 2 feet 8 inches. Deposits more than 1 foot 8 inches in height are confined in the main to small areas in Union, Salt Creek, and Bluerock townships. The bed has been regularly worked by drifting only in Union Township. The conditions for mining are excellent as far as the roof and floor are concerned, as the coal is overlain by a tough shale and underlain by a hard siliceous clay. The Harlem is a bright, dense coal which in places varies towards the cannel type. Owing to its oily nature it burns readily, but gives a smoky or sooty flame.

AMES LIMESTONE

The next member above the Harlem coal in the geological column of Muskingum County is the Ames limestone which is of importance for its stratigraphic interest if not for its economic value. In the reports of the First Geological Survey of Pennsylvania the bed was called the Green Fossiliferous limestone; in the works of Dr. J. J. Stevenson of the Second Survey the Crinoidal limestone; and in the works of E. B. Andrews of the Geological Survey of Ohio the Ames limestone from exposures observed in Ames Township, Athens County. The term Ames is now in general use in Ohio, West Virginia, and Pennsylvania. Regarding this limestone Condit says:[1]

> The Ames is geologically one of the most importa t horizons in the Conemaugh as it is of great service as a stratigraphic key. Although seldom more than 2 or 3 feet thick and only a nodular layer over large areas, the rock has certain distinctive features which make easy its identification wherever found. There are certain lithologic characteristics which are remarkably constant and they alone enable one to distinguish it from other limestones. These may be briefly summarized as follows: It is a gray or greenish-gray limestone, ordinarily in a single bed 1 to 3 feet thick. Fossils are abundant, especially crinoids, which stand out in relief on the weathered surface. The rock on fracture shows a more or less granular, crystalline texture, due to cleavage faces of calcite, and is frequently spotted with minute, greenish, glauco itic grains.
>
> The most reliable method of identification is by means of the fossils. As the name Crinoid l would imply, crinoidal remains are abundant nearly everywhere and locally make up the body of the rock. In addition, there are numerous species of brachiopoda, pelecypoda, gastropoda, and other forms, which altogether make this one of the richest fossil-bearing horizons in the Pen sylvanian series. The entire fossil list from the Ames of Ohio includes 87 species, and in one locality alone,

[1]Geol. Survey Ohio, 4th Ser., Bull. 17, p. 29.

near New Concord, 60 species were found. But such prolific occurrences are unusual, and more commonly the total fauna in any one locality numbers less than 20 species.

For a list of the marine life of the Ames limestone the reader is referred to Chapter V, Bulletin 17, of this Survey. The limestone is a remarkably persistent bed in Muskingum County, where it extends diagonally across the southeastern part of the area. The thickness of the stratum varies from 8 inches to 5 feet, but averages about 1 foot 7 inches. In most of the area the member is composed of a single layer of limestone, but in some localities it is made up of two layers of limestone, which are separated only by a bedding plane or by a few inches of shale, also fossiliferous. This limestone in Muskingum County is everywhere overlain and underlain by many feet of siliceous shale and shaly sandstone, which owing to their resistance to weathering agencies form such steep slopes along the hillsides, or such mound-like knobs along the ridges, that the horizon becomes a very noticeable topographic feature. In this county the Ames limestone is usually dark-gray, ferruginous, and crystalline. On the average the position of the member is 172 feet below the Pittsburgh coal, and 205 feet above the Upper Freeport coal. This bed is present above drainage in parts or all of Clay, Brush Creek, Harrison, Bluerock, Meigs, Wayne, Salt Creek, Rich Hill, Perry, Union, Salem; and Highland townships.

In Clay Township the Ames limestone is present near the summits of the high knobs in Section 13, in the eastern part of Section 12, and in the eastern and southern parts of Section 14. The rock is everywhere very fossiliferous and has the usual crystalline texture. This limestone in Brush Creek Township is a very persistent bed along the ridges in the area south of Cannelville, and east of Brush Creek as far north as Irish Ridge.

Deposits of Ames limestone are regularly present along all the ridges in Harrison Township as far north as Butterbean Ridge. The main stratum of limestone is from 1 to 2 feet in thickness, and an upper layer, which is present in some areas, measures from a few inches to 1 foot. The rock is fairly pure and fossiliferous. The position of this limestone with reference to other prominent beds in the lower part of the Conemaugh formation is well shown in the following record, taken at Stone, in Section 30:

	Ft.	In.
Limestone, *Ames*	1	5
Shales and covered	47	--
Sandstone, massive, *Cow Run*	28	--
Shale and covered	10	--
Coal blossom, *Anderson*	1	--
Covered	5	--
Limestone, flinty, *Cambridge*	4	--
Shale and covered	7	--
Shale and shaly sandstone	32	--

		Ft.	In.
Sandstone, shaly		20	6
Shale, gray		7	--
Coal, hard, *Mahoning*		--	6
Clay, siliceous		2	--
Shale with parts covered		23	--
Coal, cannel, bony	*Upper Freeport*	--	9
Coal, good		1	6
Shale		--	1
Coal, good		2	4

The Ames limestone is above drainage in all of Bluerock Township except the southeastern part, where the ridges are high and the streams not deeply intrenched. The stratum varies in thickness from 10 inches to 2 feet 8 inches, but it measures on the average about 1 foot 6 inches. This limestone is above drainage along Meigs Creek and its tributaries in sections 19, 20, 29, 30, and 32 of Meigs Township. From the frequency with which the member was exposed along the Meigs Creek Valley it appears to be very steady in extent and also in thickness. The maximum and minimum measurements obtained were 10 inches and 1 foot 10 inches. Along the road just east of the Toadtown School, in Section 30, both the Ames and Gaysport members were exposed. The interval of separation is about 12 feet. Along the road in the eastern part of the same section the Skelley limestone, 2 inches in thickness, lies 45 feet above the Ames.

In Wayne Township the Ames limestone is present only on a few of the high knobs in sections 19, 29, and 32. The Ames is by far the most constant bed of limestone above drainage in Salt Creek Township, as the stratum is everywhere present on its proper horizon, whereas the others are fitful and uncertain. The rock has the usual light-gray color and crystalline texture and is rather pure in composition. Another feature is the regularity in thickness of the stratum, which is about 2 feet in most of the area. In a few places, however, some diminution was occasioned by erosion as the basal portion is conglomeratic in structure.

In Rich Hill Township the Ames limestone is above drainage along White Eyes Creek in Section 16, along Williams Fork in sections 4, 5, 6, 7, 8, and 9, and along Buffalo Fork in sections 16, 17, 18, 19, 20, 21, 28, 29, and 30. The member is very constant in both extent and thickness. This limestone is also present near the summits of the high ridges and knobs east of Salt Creek and south of the National Road in Perry Township. The weathered blocks are ferruginous and very fossiliferous.

The many exposures of Ames limestone observed in Union Township show that the bed extends in practically an unbroken sheet across the area, except where it has been removed by the various forces that intrenched the valleys in the old Allegheny Plateau. Owing to the

influence of the Otsego anticline that extends across the area the dip of the bed lacks the uniformity observed in the townships so far described. Just south of the Baltimore & Ohio Railroad on the farm of W. P. Caldwell, which is located in Section 8, the Ames member has exceptional thickness, as it measures about 5 feet. The upper 4 feet of rock is shaly and very fossiliferous. This condition, however, is only local, for in the cut of the railroad a short distance west of this exposure the bed measures only 2 feet 1 inch.

The only areas of Ames limestone in Salem Township are on the high knobs of the ridge about 1½ miles east of Burnt Mill School, where the bed has an elevation of nearly 1,050 feet. The deposits of this limestone observed at a few other places along the ridge were also about 1 foot in thickness. The rock is rather ferruginous, but very fossiliferous, and is thus easily identified.

With the same steadiness with which the member enters Muskingum County from Morgan on the south, the Ames limestone passes from Muskingum into Guernsey on the east. Moreover, the bed retains the same general characteristic across this entire area. The most northern exposures of this limestone in Muskingum County are in northern Highland Township, in which area, owing to the anticline that crosses it from north to south, the member everywhere lies near the summits or well up the slopes of the main ridges. The maximum and minimum measurements of the deposits observed were 3 feet and 10 inches respectively. In general the thicker deposits are less ferruginous than the thinner ones, and hence are lighter in color. Along the ridges in parts of this area the limestone is not only rich in the remains of marine life that flourished in the ancient Conemaugh sea, but is so weathered that the fossils are made more distinct.

Economic Value

The Ames limestone in Muskingum County, although a very interesting and important bed for its stratigraphic features and for its marine fauna, must be assigned a trivial place for its economic worth. Although the bed rarely reaches 3 feet in thickness and averages only about 1 foot 7 inches, it is found over a wide area in parts of which other limestones are poorly developed or even wanting. Owing to the weather-resistant character of the rock many exposures are present along the hillsides and along the stream beds so that small quantities of material are available at a low cost. The composition of this limestone is shown by the following analysis of a sample taken along the road south of New Concord and analyzed by Prof. D. J. Demorest:

Silica, SiO_2	4.77
Alumina, Al_2O_3	1.83
Ferric oxide, Fe_2O_3	6.34

Titanic oxide, TiO_2	.10
Lime, CaO	46.28
Magnesia, MgO	1.45
Phosphorus, P	.18
Sulphur, S	.14

By calculating these components to their approximate mineral analysis the results are as given below:

Clay, $Al_2O_3.2SiO_2.2H_2O$	4.63
Quartz, SiO_2	2.62
Pyrite, FeS_2	.30
Siderite, $FeCO_3$	7.64
Rutile, TiO_2	.10
Calcium phosphate, $3CaO.P_2O_5$	.90
Calcium carbonate, $CaCO_3$	81.77
Magnesium carbonate, $MgCO_3$	3.05
Total	101.01

The above analysis shows that the material is low-grade and thus somewhat limited in its uses. The total quantity of minerals available for soil enrichment is only about 85 per cent, which is considerably less than in most of the thicker beds in the county. Such a limestone on calcination gives a product which does not slake readily, and which has a dark-gray color. The Ames is a dense, tough limestone, well suited for road building, but as the deposits are thin the quantity available in any given locality is not large. However, the member may be drawn upon for at least a part of the supply in outlying regions where other material is not readily available.

GAYSPORT MEMBER

In local areas, in Muskingum County, a well-defined fossiliferous bed occurs on the average about 16 feet above the Ames limestone and 20 feet below the Skelley member. The stratum is bedded in the same series of gray shales and shaly sandstones in which the Ames limestone is found, and it thus represents another calcareous sediment laid down during this general invasion of the sea. In composition the rock varies from a calcareous sandstone to a ferruginous, siliceous limestone and in thickness from 3 inches to 2 feet 6 inches. The average measurement of the stratum, however, is about 1 foot 2 inches. Owing to the fact that this bed is best developed in the vicinity of Gaysport, in Bluerock Township, it is called in this bulletin the Gaysport member.

This limestone differs from the Skelley, with which it may be confused, in several respects. The Gaysport is everywhere a very impure limestone or a calcareous sandstone, whereas the Skelley is a relatively pure limestone. As previously stated, the Gaysport member is bedded in gray shales and shaly sandstones, but the Skelley limestone with

few exceptions is stratified in red or mottled clay shales. Although both beds are fossiliferous, the Skelley contains by far the most preserved forms and the largest number of species. All the fossils noted were types common to the underlying Ames limestone, but the paleontology of the member has not been carefully studied. The Gaysport member was observed in Bluerock, Brush Creek, Meigs, Rich Hill, and Salt Creek townships. Deposits of this bed were noted also as far south as Malta in Morgan County, but they appear to be wanting in the northern part of Muskingum County and in the eastern part of Guernsey.

SKELLEY LIMESTONE

The Skelley limestone, which is sometimes called the Upper Ames, and which was named from exposures at Skelley Station on the Pennsylvania Railroad, in Jefferson County, is found with some regularity in its extension across the southeastern part of Muskingum County. The position of the member in eastern Ohio is defined as lying immediately over the Duquesne coal, which stratum, however, is wanting in the area now under consideration. The position of the Skelley limestone is, therefore, best referred to that of the Ames limestone, which lies nearly 38 feet below it. In Muskingum County the bed is everywhere thin, rarely having a thickness of 1 foot and averaging only about 4 inches. With few exceptions this limestone is both overlain and underlain by clay shales of a red color and of a plastic nature. The limestone varies considerably in composition. At its best it is a light-gray, granular, crystalline rock resembling the Ames. In places it is a dark ferruginous limestone which when weathered has the appearance of an impure iron ore. Another modification, where the stratum is directly overlain by the Morgantown sandstone, is a very siliceous limestone containing many small nodules of iron ore.

In this county the Skelley limestone is everywhere fossiliferous and in places it is rich in the remains of the life that flourished in this ancient Conemaugh sea. The fossils were not studied with care, but the types most common in the Skelley are those common to the Ames. The Skelley is the highest limestone of marine origin in the rock column of the Conemaugh formation, and this general horizon really marks the boundary between the great series of red clay shales with successive deposits of marly and nodular limestones of fresh-water origin, and the underlying series of gray shales and sandstones with well-stratified limestones of marine origin, thin coal beds, and unsteady red clay shales. In this area by far the most pronounced change in the character of the rocks in the formation takes place at or only a few feet below the Skelley limestone. Deposits of this member were observed in Brush Creek, Harrison, Bluerock, Meigs, Salt Creek, Union, and Highland townships and the horizon is above drainage also in Rich Hill. Owing to the fact that the stratum is thin and that it is bedded

in clay shale which slumps badly, the Skelley limestone is easily overlooked and is probably far more persistent than is usually suspected.

BIRMINGHAM SHALE

The Birmingham is a siliceous, buff-colored shale, which was named by Dr. J. J. Stevenson from exposures at Birmingham, a suburb of Pittsburgh. The Duquesne coal or the overlying Skelley limestone is taken as the base of the bed and the Elk Lick coal as the top. However, as the Elk Lick coal is wanting in Ohio the upper limit of the bed is thus indefinite. Where well developed the thickness of this shale is from 30 to as much as 50 feet. In Muskingum County the interval of the Birmingham member is largely taken by red and mottled clay shales which in many places are very calcareous owing to the presence of marly limestone. Moreover, in other parts of the area the Morgantown sandstone occupies a part of the interval. The deposits of Birmingham shale are therefore limited in extent and are seldom of normal thickness.

The stratigraphy of the Birmingham member in the southern part of the county is shown by the following record taken in Section 24, Bluerock Township:

	Ft.	In.
Sandstone, shaly	3	--
Shale, buff, *Birmingham*	15	--
Shale, red	6	--
Limestone, *Skelley*	--	2

This brownish or yellowish-gray shale in some state of development was also observed in local areas in Meigs, Salt Creek, Rich Hill, and Union townships, and it is rather persistent in the western part of Highland Township.

As previously stated, the Birmingham shale is not a persistent bed in Muskingum County, as its place is largely taken by red clay shales or by local deposits of Morgantown sandstone, which appears to have been deposited at about the same time. The stratification planes and the fineness of the material indicate that this shale was laid down in quiet waters, or that it is an off-shore deposit. No fossils were found in the member, although they may be present, as the unweathered material was seldom favorably exposed for examination. As the material has no special value, even for ceramic products, it need not be considered further.

MORGANTOWN SANDSTONE

The Morgantown sandstone, which was so named by Dr. J. J Stevenson, from its typical exposures near Morgantown, West Virginia, is the next definite bed above the Birmingham shale in the geological column of Muskingum County, as the Elk Lick coal and its associated limestone, locally present in both Pennsylvania and West Virginia, are

wanting. This sandstone is best developed in small areas in the southern part of the county where it lies mostly on or not far above the horizon of the Skelley limestone. Owing to the patchy nature of the deposits the stratigraphic position of the bed is rather indefinite and variable. Where the deposits are thick the base of the sandstone reaches nearly to the Ames limestone. The member varies in thickness from a few feet to as much as 30 feet, and varies in character from a fine-grained, drab-colored sandstone to a coarse-grained, bluish-gray rock, the basal portion of which is occasionally conglomeratic. In Muskingum County the Morgantown sandstone is present in Brush Creek, Harrison, Bluerock, Meigs, Salt Creek, Rich Hill, Union, and Highland townships, but in most of the areas the deposits are scattered and the bed either thin or broken. The member is most conspicuous along the Muskingum Valley in the southern part of Bluerock Township, and along Meigs Creek and its tributaries in the southwestern part of Meigs Township. The following record, taken in the southeastern part of Section 32, Bluerock Township, shows very well the general stratigraphy of the bed:

	Ft.	In.
Shale, siliceous	6	--
Sandstone, massive, upper part shaly, *Morgantown*	16	--
Sandstone, calcareous, with small ore nodules, *Skelley* horizon	1	--
Shale and shaly sandstone	1	--
Sandstone, calcareous, fossiliferous, *Gaysport*	1	--
Shale, gray	20	--
Limestone, *Ames*	--	11

In this vicinity the Morgantown sandstone is very weather resistant and forms a line of cliffs or steep escarpments along the valley near the 900-foot contour. In its extension northward along the Muskingum Valley the bed becomes unsteady and in places wanting.

RED SHALE STRATA

In Muskingum County the interval from the Skelley limestone to the Summerfield limestone, and in places even from the Ames limestone to the Pittsburgh coal, is largely made up of a series of light and highly-colored clay shales, in which irregular deposits of marly and nodular limestone and thin lenticular beds of gray shale and buff sandstone are locally interstratified. These shales are well represented in Bluerock, Meigs, eastern Salt Creek, Rich Hill, and Union townships. The light-colored shale is usually rich in marly calcareous matter, and in places it is the parting material between the more definitely stratified beds of limestone. The clay substance is extremely fine and very plastic.

These deposits are uncertain in extent and in thickness and they vary greatly in vertical range. The main body of this series of clay shales, however, is mottled or highly colored. The material in some

beds shows no structure whatever, but that in others contains well-defined stratification planes which are usually closely spaced. The color of these shales varies from a light-pink to reddish-brown, and is only slightly dependent on the extent of weathering. The principal staining pigments are ferric oxide and its hydrated forms, which are in a very finely divided state, and thus have a high coloring power. These beds are not only colored at the surface, but, as shown by drill records, they are in the same condition under heavy covering. Regarding the origin of such red beds there is a wide difference of opinion among geologists. In general the views held are that these sediments, which had been well oxidized even before transportation, were laid down under warm but rather arid climatic conditions in shallow and probably brackish water in which there was a scarcity of organic matter. The coloration is evidently due to the conditions of formation as the quantity of iron in the red shale is not especially different from what it is in the gray or blue varieties.

These shales are very plastic and impervious, and where they outcrop well up the slopes of the hills are much given to slumping, so that natural terraces or benches are formed. In general the topography along the outcrop of this series of red beds in the upper part of the Conemaugh formation is much more gently rolling than it is along the outcrop of the more siliceous deposits in the lower part. Owing to the high content of lime in these shales the derived soils are especially adapted for blue grass and for legumes. They are also well adapted for fruit raising as shown by the fine products of parts of the region.

CLARKSBURG LIMESTONE

The Clarksburg limestone was not positively identified in Muskingum County, but on its horizon, which is about midway between the Ames limestone and the Pittsburgh coal, isolated deposits of impure nodular limestone are present in parts of the area. The material is of a buff color and generally siliceous. The deposits usually consist of two, three, or even more beds of limestone, separated by thin strata of shale and ore from 2 to 10 feet in thickness.

CLARKSBURG COAL

The Clarksburg coal, which is a conspicuous bed in parts of West Virginia, especially near Clarksburg, and in western Maryland, is wanting or very indistinct in Muskingum County. In typical sections its position is just above the Clarksburg limestone and not far below the Connellsville sandstone. In a few places in Union and Meigs townships thin streaks of dark shale or irregular layers of papery coal, that appear to mark the horizon, occur in a few feet of gray shale or shaly sandstone lying about 80 feet below the Pittsburgh coal. The Clarksburg was nowhere observed as a well-defined coal bed.

CONNELLSVILLE SANDSTONE

The Connellsville sandstone, which was so named by Dr. J. J. Stevenson, from massive deposits exposed along the streams in the vicinity of Connellsville, Pennsylvania, is also poorly defined in Muskingum County. In this area the place of the member, which is in the interval between the Clarksburg coal and the Summerfield limestone, is largely taken by highly-colored clay shales with more or less marly limestone. In fact, but few patches even of shaly sandstone were observed.

SUMMERFIELD LIMESTONE

The Summerfield limestone, which is generally considered correlative with the Lower Pittsburgh limestone of Pennsylvania and West Virginia, is rather regularly present in Bluerock, Meigs, southeastern Salt Creek, Rich Hill, and Union townships. The interval from the base of the limestone to the Pittsburgh coal varies from 47 to 65 feet, but averages about 54 feet. Further, the well-defined beds of limestone are usually separated from the Lower Little Pittsburgh coal by 5 to 15 feet of red or mottled shale, which also contains more or less calcareous material, so the upper limit of the Summerfield member is rather indefinite. In places the basal stratum is somewhat conglomeratic in character and is from 1 to 3 feet in thickness. The member in most of the area is made up of several layers of limestone separated by thin beds of calcareous shale. The layers are very unsteady in both thickness and extent, but as some thin and become wanting others usually appear either above or below to take their places. The total thickness of the deposits varies from 3 feet to as much as 15 feet, but averages nearly 6 feet. The Summerfield limestone contains no fossils except *Spirorbis* and some minute types which are regarded as fresh-water species. The material is usually of a light-gray or buff color, and from appearance has fair purity.

LOWER LITTLE PITTSBURGH COAL

The Lower Little Pittsburgh coal was named from deposits exposed in Somerset County, Pennsylvania, where the bed lies about 50 feet below the thick Pittsburgh coal and just above the Lower Pittsburgh limestone. In Muskingum County a bed, which lies on the average about 37 feet below the Pittsburgh coal, and 11 feet above the Summerfield or Lower Pittsburgh limestone, is considered correlative with the stratum in Pennsylvania, and also with that in the northern part of West Virginia. This coal is thin and shaly and the deposits are local in extent. The member is represented in Bluerock, Meigs, and Rich Hill townships.

Along the road in the northwestern corner of Section 15, Meigs Township, the Lower Little Pittsburgh coal lies about 93 feet below the Meigs Creek coal, as shown by the following carefully measured section:

	Ft.	In.
Coal, *Meigs Creek*	4	--
Shale with small limestone nodules	9	--
Limestone	1	5
Covered	19	4
Sandstone, shaly	33	--
Covered, horizon of *Pittsburgh* coal	6	--
Sandstone, thin-bedded and shaly	20	8
Covered	2	6
Coal blossom, *Lower Little Pittsburgh*	1	--

In the eastern part of Section 9 measurements show that the interval from the Lower Little Pittsburgh coal to the Pittsburgh is 30 feet. A thin layer of shaly coal on this horizon was also observed along the road in Section 28, Bluerock Township. Other deposits were noted in sections 21 and 22 of Rich Hill Township. The Lower Little Pittsburgh coal in Muskingum County has no value, as the coal is but a few inches in thickness and shaly in character.

BELLAIRE SANDSTONE

The Bellaire sandstone, which is a massive bed in the eastern part of the State, especially near Bellaire in Belmont County, and which is generally considered correlative with the Lower Pittsburgh sandstone of Pennsylvania, is poorly defined in Muskingum County. Like most sandstones its vertical range is far from being constant, but in a general way its position is about midway between the Lower Little Pittsburgh and the Pittsburgh coals. In places it occupies nearly all of this interval, but in other localities the most conspicuous beds are found only in the upper portion. The member is most persistent in Rich Hill Township, but deposits are also found in local areas in Bluerock, Meigs, Salt Creek, and Union townships. In Muskingum County the Bellaire sandstone is generally shaly in character and, therefore, has no value worthy of consideration.

UPPER LITTLE PITTSBURGH COAL

The Upper Little Pittsburgh coal, which has sufficient thickness for drift mining in local areas of Somerset County, Pennsylvania, is wanting in Muskingum County. No carbonaceous shale even was observed on the horizon, the probable position of which is about 20 feet below the Pittsburgh coal and nearly 3 feet below the Upper Pittsburgh limestone. Calcareous shale is the prevailing rock in this interval.

UPPER PITTSBURGH LIMESTONE

The Upper Pittsburgh limestone, the usual position of which is from 10 to 20 feet below the Pittsburgh coal, is a rather persistent bed in the southeastern part of Muskingum County, in fact it appears to be as constant as the overlying coal. The more prominent exposures show from three to six well-defined layers of limestone, separated by

red or light argillaceous shales, which also contain considerable calcareous matter. These limestone strata are from a few inches to as much as 2 feet in thickness, and the shale partings have much the same measurements. Moreover, horizontally these layers are unsteady, but as one bed gradually thins to a feather edge and then disappears another usually sets in near the horizon to take its place. In this area the average thickness of the member is about 10 feet. This limestone is somewhat siliceous, argillaceous, and ferruginous in composition, buff to bluish-gray in color, and amorphous in structure. The fossils present are few and minute and are regarded as fresh-water forms. The member is present in Bluerock, Meigs, southeastern Salt Creek, Rich Hill, and Union townships.

The following record, which shows the general structure and position of the Upper Pittsburgh limestone in Muskingum County, was taken along the road in Section 28, Bluerock Township:

		Ft.	In.
Coal blossom, *Pittsburgh*		1	--
Clay shale, colored		5	--
Limestone, nodular		1	--
Shale	*Upper Pittsburgh*	2	--
Limestone with shale partings		2	--

CHAPTER V

MONONGAHELA FORMATION

The Monongahela formation, which was first described by H. D. Rogers from strata exposed along the Monongahela River in Pennsylvania, is the upper division of the Pennsylvanian system. It extends from the base of the Pittsburgh coal to the roof shale of the Waynesburg coal, which limits were fixed more by the thickness and importance of the coal beds than by lithologic changes in the rocks or by disconformity of strata. In Muskingum County the Monongahela formation contains four well-defined coal members, only one of which is of importance. The coals in this formation are slightly thicker than they are in the underlying Conemaugh formation. The most conspicuous rocks in the Monongahela division are clay shales, which are usually colored and calcareous, and limestones which vary from marly material to well-stratified beds. As previously stated, these are the prevailing rocks also in the upper half of the Conemaugh formation. No pronounced change in the character of the materials or in the regularity of deposition is apparent at the horizon of the Pittsburgh coal, which marks the division of the two formations. In fact, the greatest accumulation of limestone is present above the Meigs Creek coal, which is well up in the Monongahela. On the whole, sandstones are no more abundant or significant in the Monongahela formation than they are in the Conemaugh. As far as this region is concerned the line between the two divisions of rocks is arbitrary, and that between the Monongahela and Dunkard is established on but little better evidence.

Regarding the origin of these rocks Dr. I. C. White says:[1]

> No marine fossils have ever been discovered in any of the limestones of the Monongahela series and everything indicates that the deposits are of fresh-water origin. The black slates always contain fish remains in the shape of scales and teeth, but nothing is known of their affinities, because they have never been studied. The water may have been estuarine and slightly brackish, but the minute Cyprian and Estherian-like forms whose skeletons—mostly broken and p lverized—make up the principal mass of the Monongahela limestone, testify clearly against their marine origin.

In Muskingum County the Monongahela formation is approximately 248 feet in thickness and is present in Bluerock, Meigs, Salt Creek, Rich Hill, and Union townships. The upper members are found, however, only in Meigs Township.

[1]Geol. Survey of West Virginia, Vol. II, p. 125.

PITTSBURGH OR NO. 8 COAL

Stratigraphy and Extent

The lowest member of the Monongahela formation is the Pittsburgh or No. 8 coal, which was so named by J. P. Lesley, in 1856, from exposures near Pittsburgh, and which is regarded the most valuable single bed in the entire Pennsylvanian system. In its extension westward from the main basin, however, this great coal bed decreases in thickness so much that in Muskingum County it is of little interest aside from its stratigraphic features. The horizon is well defined across Bluerock, Meigs, southeastern Salt Creek, Rich Hill, and Union townships, but the coal is everywhere thin and usually impure. On the average the member lies about 55 feet below the well-developed Meigs Creek coal and 172 feet above the fossiliferous Ames limestone, which are the best benches for reference. No mines were found in this coal when the region was visited in 1916-17, and as far as observed it has been prospected at only a few places.

Bluerock Township.—The most western exposure of Pittsburgh coal observed in Muskingum County was along the road in the south central part of Section 28, Bluerock Township, where the elevation of the bed is about 1,065 feet above tide. In the southeastern corner of this section, near the Bald Knob School, the following record was measured:

	Ft.
Coal blossom, *Meigs Creek*	3
Clay	3
Sandstone	4
Clay shale, calcareous, with many layers of thin to medium-bedded limestones	38
Coal blossom, *Pittsburgh?*	2

The thin blossom of the Pittsburgh coal, lying about 50 feet below the Meigs Creek member, is rather persistent along the high ridges in the vicinity of Ruraldale. The deposits in Bluerock Township extend as far north as sections 1, 12, 14, 15, and 16. In the extreme northeastern corner of Section 1 the coal has been prospected and is reported to be 1 foot 10 inches in thickness and to be of fair quality.

Meigs Township.—In Meigs Township the Pittsburgh coal, although only about 1 foot thick, and impure, appears to be rather steady, especially in the northern part, as the blossom was observed with some regularity. Owing to the dip of the rocks the bed lies well up the slopes of the ridges in the western part, but not far above drainage in the eastern part. In places in the southern part of the township the member appears to be wanting or represented by only a thin bed of carbonaceous shale. No mines were observed in the area.

Salt Creek Township.—The blossom of the Pittsburgh coal is present at an elevation of approximately 1,010 feet on the high knobs

and ridges in sections 24, 25, and 36, of Salt Creek Township. The bed was formerly worked in a small way along the ridge in Section 36, where it is stated to be about 2 feet in thickness, and to be made up of two coal benches separated by a few inches of clay.

Rich Hill Township.—The Pittsburgh coal is above drainage in nearly all of Rich Hill Township, but the bed is best represented along its western outcrop. In the eastern part of the township the exposures indicate that the member is thinner and more fitful. In years past small mines were operated at several places in the western part of the area, but when the region was visited in 1916-17 no openings were observed. The thickness of the bed is stated to be from 2 feet to 2 feet 6 inches. In this locality the position of the Pittsburgh coal is about 160 feet above the Ames limestone, whereas in Section 6, as shown by Condit, it is 196 feet above this member.

Union Township.—Owing to the influence of the Otsego anticline the Pittsburgh coal lies near the summits of the high ridges and knobs in all of Union Township. From outcrop exposures the coal has fair thickness and regularity in the central and southern parts of the township, but it is thin and uncertain in the western and northern parts. The most northern exposure of Pittsburgh coal observed in Muskingum County is near the forks of the road in the northern part of Section 4, where its elevation is nearly 1,165 feet above tide. At this place a carefully-measured section gave an interval of 172 feet between the Pittsburgh coal and Ames limestone.

On the farm of Frank Wilson, Section 12, 2 miles southwest of New Concord, the coal is reported as cannel, but it soon passes into soft coal as is shown on the opposite side of the ravine from the cannel exposure. On the farm of Samuel Noble, 2½ miles south of New Concord, the coal is reported 46 inches thick, and all cannel except about 1 foot of soft coal at the top. This is probably the greatest thickness of this seam in Muskingum County, but it is only a very local deposit, as it thins rapidly to 30 or 32 inches.[1]

Economic Value

From outcrop exposures the field of Pittsburgh coal in Muskingum County, 2 feet or more in thickness, is not more than 10 square miles, and is confined to small areas in northern Bluerock, southeastern Salt Creek, western and central Rich Hill, and southern and central Union townships. The member is rather regularly divided into two coal benches, separated by a clay or a shale parting, which is somewhat detrimental in mining. The upper coal bench is much thinner and more impure than the lower one, and in places is left for the roof of the mine. In most of the field the roof of the coal is a carbonaceous shale or shaly sandstone which is tough and strong, but in some localities it is a clay shale which is calcareous, soft, and yielding. The coal was not sampled by the writer for chemical analysis as no mines were found in operation

[1]Geol. Survey Ohio, 4th Ser., Bull. 9, p. 63.

From reports of people who have used it, the coal is satisfactory for general purposes, and is superior in quality to the overlying Meigs Creek. It is an oily, free-burning coal, with only a moderate quantity of ash and sulphur. In small areas both bituminous and cannel coal are present on the horizon.

UPPER PITTSBURGH SANDSTONE

The Upper Pittsburgh or Pittsburgh sandstone of H. D. Rogers lies on or not far above the Pittsburgh coal, and in places so expands that it not only replaces the Redstone members, but a part of the Sewickley beds as well. In Muskingum County the member is rather prominent in parts of Meigs and Rich Hill townships, but it is represented also by local deposits in Bluerock, southeastern Salt Creek, and Union townships. The material at its best is light-gray, rather coarse-grained and loosely cemented, and is of little value. Most of the deposits, however, are more or less shaly in character, and often pass laterally into siliceous shale. The thickness of the sandstone varies from 1 to 40 feet, but the usual measurement is between 10 and 20 feet.

REDSTONE LIMESTONE

The Redstone limestone, the position of which is just below the Redstone or Pomeroy coal, and not far above the Pittsburgh coal, is not a steady bed in Muskingum County, as its place is largely taken by the Upper Pittsburgh sandstone or by gray siliceous shale. The member, where well developed, is made up of several layers of fresh-water limestone, which are separated by calcareous and usually colored shales. Owing to the persistent absence of the Pomeroy coal and sandstone, to the close association of the overlying Sewickley limestone, and to the extensive slumping along the horizon, the upper limit of the Redstone member is hard to define.

The usual position of the member in this county is given in the following composite section, taken along the road in Section 7, Meigs Township:

	Ft.	In.
Coal blossom, *Meigs Creek*	2	--
Clay shale	2	--
Limestone, thin to medium-bedded in clay shale, with parts covered, *Sewickley*	10	--
Clay shale, with parts covered	12	--
Limestone, thin, nodular, in clay shale, *Redstone*	2	--
Clay shale, red and drab	13	--
Sandstone, shaly, *Upper Pittsburgh*	4	--
Shale, gray	5	--
Coal blossom, shaly, *Pittsburgh*	--	6

Other localities in which the Redstone limestone is well developed are in the vicinity of the Bald Knob School, in Section 28, and along the ridges near Ruraldale in Bluerock Township. Local deposits

are also present in the central part of Rich Hill Township. The main importance of the Redstone limestone and its associated calcareous shales in Muskingum County is their contribution of calcareous components to the soils along the horizon, which are thereby increased in productiveness.

POMEROY, REDSTONE, OR NO. 8a COAL

The Pomeroy or Redstone coal was first described by H. D. Rogers from exposures along Redstone Creek in Fayette County, Pennsylvania. It is a very unsteady bed, but has sufficient thickness for mining in parts of Pennsylvania, West Virginia, Maryland, and Ohio. The important field in this State is near Pomeroy in Meigs County, but it has good thickness also in parts of Gallia and Lawrence counties. In Muskingum County the member is present in but few places, and there it is represented only by a few inches of shaly coal or carbonaceous shale.

POMEROY SANDSTONE

The Pomeroy sandstone, which is such a conspicuous bed near Pomeroy, Meigs County, where it forms the roof of the Pomeroy or Redstone coal, is poorly defined in Muskingum County, as its place is taken by highly-colored clay shales or by these with nodular and marly limestones. Thin shaly deposits of sandstone are locally present on this horizon in southern Bluerock and Meigs townships, but none were noticed in Rich Hill or Union. The member is of no importance even for stratigraphic purposes.

SEWICKLEY LIMESTONE

The Sewickley limestone, described by J. J. Stevenson in the reports of the Pennsylvania Geological Survey, is a rather persistent member in Muskingum County, although it varies considerably in both structure and thickness. The layers of limestone vary from a few inches to 2 or 3 feet in thickness and are uncertain horizontally. In places they are closely spaced, but in other localities they are separated by shales which vary from a few inches to several feet in thickness. Both the overlying and underlying shales, as well as the shale interstratified with the limestones, are usually very calcareous and highly colored, so that the exact limits of the Sewickley member are rather indefinite. The interval occupied by the limestone layers varies from 1 to as much as 22 feet, but on the average it is about 10 feet. Further, the interval from the Meigs Creek coal to the upper layer of limestone is erratic as it expands from 2 feet to as much as 20 feet, whereas that from the coal to the lower layer changes from 10 to 30 feet. Like the limestone in the upper part of the Conemaugh, the Sewickley member is of fresh-water origin, and was deposited under similar conditions. The member is present in Bluerock, Meigs, Salt Creek, Rich Hill, and Union townships.

Bluerock Township.—The Sewickley limestone is regularly present along the high ridge and its spurs extending from Section 15 southeast past Ruraldale to Section 36, and west from that village to the Bald Knob School in Section 28. Deposits are also present on the knobs in the eastern part of sections 12 and 13. The general stratigraphy of the member is given in the following record, taken along the road in the southeast corner of Section 14:

		Ft.	In.
Shale and shaly sandstone, gray		20	--
Coal blossom, *Meigs Creek*		3	--
Clay shale, with marly limestone		8	6
Limestone, light	*Sewickley*	--	6
Clay shale, light, with marly limestone	*Sewickley*	4	4
Limestone, light	*Sewickley*	--	8
Clay shale, red, with some marly limestone		18	--
Sandstone, shaly, with siliceous shale, gray		16	--
Coal blossom, shaly, *Pittsburgh*		--	6
Clay shale, with thin layers f limestone		5	6
Limestone, nodular, *Upper Pittsburgh*		2	--

In sections 15 and 22 the Sewickley member measures from 5 to 15 feet and consists of several layers of limestone 2 to 10 inches or even more in thickness, interbedded with shale. The deposits near Ruraldale are also much the same in character, but in places near the Bald Knob School, in Section 28, they are somewhat thin owing to the presence of sandstone.

Meigs Township—In Meigs Township the Sewickley limestone outcrops near the summits of the high hills in the western part, but near drainage level along the stream in the eastern part. The member is seldom wanting and may be easily located owing to its proximity to the Meigs Creek coal, which is well developed in most of the area. The deposits usually consist of several layers of limestone which are rather closely spaced and which have a total thickness of 5 to 20 feet. The member has excellent thickness in the vicinity of High Hill as is shown by the following measurement taken in the hollow to the west of the village:

		Ft.	In.
Shale, siliceous		15	--
Coal, weathered	*Meigs Creek*	1	8
Clay shale	*Meigs Creek*	--	10
Coal	*Meigs Creek*	2	8
Covered		5	8
Limestone, *Sewickley*		6	4

North of High Hill the member varies from 10 to 20 feet in thickness. In places in the southern part of the township the Sewickley member is wanting as its place is taken by shaly sandstone.

Salt Creek Township.—The only deposits of Sewickley limestone in Salt Creek Township are found along the high ridges and knobs

in sections 25 and 36, and at an elevation of nearly 1,070 feet. The material has the usual light-gray or buff color, blocky form, and compact texture. The member is separated from the overlying Meigs Creek coal by only a few feet of calcareous shale and has excellent thickness, in places expanding to as much as 20 feet.

Rich Hill Township.—In a general way the Sewickley limestone is due along all the high ridges in Rich Hill Township except those in the northwestern part, but the member lacks the continuity and development that it has in the townships to the south. In most of the area not more than two or three layers of limestone are present and in places only one stratum was observed. These limestones are bedded in shale, usually colored and calcareous, and are uncertain in thickness and in extent. In parts of the township the member is represented only by scattered nodules of limestone in the clay shales. No fossils were observed either in the limestone or in the associated material.

Union Township.—In Union Township deposits of Sewickley limestone are present on the knobs of the main ridge that extends from Rix Mills to New Concord. The best exposure observed is near the crossroads in Section 12, where the member consists of nodular limestone in clay shale. At this place the thickness of the deposit is about 6 feet, its elevation nearly 1,110 feet, and its position above the Pittsburgh coal approximately 50 feet.

Economic Value

Like most of the fresh-water limestones in the lower part of the Monongahela and in the upper part of the Conemaugh formation the Sewickley is a light-gray, rather hard but brittle, non-crystalline limestone of fair purity. The rock is everywhere siliceous in character and in places along the outcrop where weathering agencies are active it is so impregnated with iron oxide that it has a buff or reddish color. It is doubtful whether it is sufficiently pure to slake readily when calcined. The main use of the Sewickley limestone in Muskingum County is evidently for road building.

MEIGS CREEK, SEWICKLEY, OR NO. 9 COAL

Stratigraphy and Extent

The Meigs Creek coal was so designated by Prof. C. N. Brown from a stream by that name, which drains the central part of the important field in Morgan, Noble, southeastern Muskingum, and southern Guernsey counties. It is considered correlative with the Sewickley coal of the First Geological Survey of Pennsylvania in which state the bed is widely persistent, but only locally important. In Muskingum County the position of the Meigs Creek or Sewickley coal is on the average 55 feet above the Pittsburgh coal and 227 feet above

the Ames limestone. The bed is regularly divided into two or three benches of coal with shale or clay partings which vary usually from ½ to 3 inches in thickness. In most of the field the roof of the member is a dark carbonaceous shale which is rather tough and strong and the floor is a calcareous, siliceous clay which is moderately soft and yielding. Owing to the presence of papery layers of impure material the stratification planes in the coal are pronounced and are closely spaced. The bed from a number of measurements averages about 4 feet 2 inches in thickness, 2 inches of which is parting material. In Muskingum County the Meigs Creek or Sewickley coal is rather persistent in both thickness and extent in eastern Bluerock, Meigs, and eastern and southern Rich Hill townships. The blossom of this coal is also present near the summits of a few high knobs in the southeastern corner of Salt Creek Township and of Union. The area of the field is approximately 27 square miles, but owing to wants and to thin covering the productive part is not more than 20 square miles. Of this only small areas have been exhausted by mining.

Bluerock Township.—In the vicinity of Ruraldale, in Bluerock Township, the Meigs Creek coal has been mined for many years for a part of the neighborhood supply. The member extends along the main ridge and its spurs from Section 15 to Section 26, thence westward to Section 33, and southeast to Section 36 where it passes into Morgan County. Small patches of coal are also present on the knobs in the eastern part of Section 12 and the northeastern part of Section 13. The elevation of the bed is approximately 1,030 feet near Bluerock Church in Section 13. The coal is very steady throughout the field and averages about 4 feet in thickness.

The Meigs Creek coal was sampled for chemical analysis at a mine on the property of Rosa Young, which is located in the northern part of Section 35. The structure and thickness of the bed at this place follow:

		Ft.	In.
Shale, hard, dark		1	--
Coal, bony, excluded	*Meigs Creek*	--	1½
Coal, good		1	--
Pyrite, irregular		--	½
Coal		--	7½
Shale		--	½
Coal		2	1
Clay, calcareous		2	--

A few small mines are also operated north of Ruraldale, but the structure of the coal is practically the same as given above. At the Bald Knob School, in Section 28, the Meigs Creek coal lies about 48 feet above the Pittsburgh coal and nearly 223 feet above the Ames limestone. The following composite record, taken along the road in sections 14 and 15, shows the general stratigraphy of the coal in the northern part of the township:

	Ft.	In.
Coal blossom, *Meigs Creek*	3	--
Clay shale	8	--
Limestone bedded in clay shale, layers from 2 to 10 inches in thickness, *Sewickley*	11	--
Shale and shaly sandstone, gray	23	--
Coal blossom, shaly, *Pittsburgh*	--	6
Clay shale	7	6
Limestone, *Upper Pittsburgh*	1	--
Clay shale, red	21	--
Clay shale, red, with some limestones near top and with parts covered	112	--
Shale, gray, with thin sandstone layers	13	6
Limestone, siliceous, fossiliferous, *Gaysport*	1	--
Shale and shaly sandstone	12	6
Limestone, *Ames*	2	8

Near Ruraldale the average of two measurements places the Meigs Creek coal 222 feet above the Ames limestone and 52 feet above the Pittsburgh coal.

Meigs Township.—The principal part of the field of Meigs Creek coal in Muskingum County is in Meigs Township, where the bed is moderately steady and has good thickness. It has been mined only in a desultory way by the farmers by drifting with short entries and by stripping along stream beds. The average thickness of the coal is about 4 feet and the maximum measurement more than 5 feet. The bed is generally divided into three coal benches separated by shale partings, each about 1 inch in thickness.

Just west of the village of High Hill, on the property of F. E. Gallogly, the Meigs Creek coal is regularly mined for local use. The record obtained follows:

		Ft.	In.
Shale, dark		4	--
Coal, somewhat bony	*Meigs Creek*	--	4
Coal, good		1	6
Shale		--	1
Coal, good		2	4
Clay and bone coal		1	--

In places in the mine the coal thickens to 5 feet. East of High Hill, in Section 4, the good coal is reported to be about 4 feet 6 inches and the partings nearly 7 inches in thickness.

On Howell's land in S. E. ¼ Section 8, Meigs Township, the Meigs Creek coal is found 39 inches thick, in three almost equal benches, having slate partings of an inch between them.[1]

In the N. E. ¼ Section 9, the Meigs Creek coal gave the following section:[2]

	In.
Rotten coal	24
Clay	20

[1]Geol. Survey Ohio, Vol. V, p. 1,070.

[2]*Idem.*, p. 1,070.

	Ft.	In.
Coal		18
Slate		1
Coal		16
Slate		1
Coal, exposed		18

In the central part of this section measurements in a mine gave the thickness of the respective strata as follows: Upper coal bench 2 feet 6 inches, shale partings 1 inch, lower coal bench 1 foot 7 inches. At this place the coal is overlain by 4 feet of dark carbonaceous shale which forms an excellent roof in mining.

Along the road in the southeastern part of Section 10 the following record was obtained in a small drift mine:

		Ft.	In.
Shale		5	--
Coal	*Meigs Creek*	1	--
Shale		--	1
Coal		2	6
Shale		--	1
Coal		1	8
Clay, calcareous		2	--

In the southeastern part of Section 12 the Meigs Creek coal is 4 feet to 4 feet 6 inches in thickness, and has a thin parting about 2 feet from the base. In this vicinity the bed is overlain by a massive, coarse-grained sandstone more than 30 feet in thickness. The outcrop exposures indicate that the coal also has good thickness in sections 13, 14, 15, 16, and 22.

On John Lett's land, in N. E. ¼ Section 26, the Meigs Creek coal is benched in the creek bank. The coal is in three benches, sep rated by inch partings. The upper bench is 16 inches, the middle, 12 inches, and the lower 24 inches.[1]

Along Brannon Fork, in Section 35, the weathered coal on the outcrop measures 4 feet in thickness, and along the road in the southwestern part of Section 36 it is 4 feet 6 inches. From mine and outcrop exposures the field of Meigs Creek coal in Meigs Township is important, but at present it is unavailable owing to a lack of shipping facilities. It extends eastward into Noble and Guernsey counties and southward into Morgan County.

Rich Hill Township.—In Rich Hill Township the Meigs Creek coal is present along the main ridges and spurs east of a line drawn from Rix Mills on the north to the southwest corner of Section 31 on the south. The bed is persistent, and in most of the field appears to be about 4 feet in thickness. The usual covering is a dark carbonaceous shale with good strength for mining purposes.

The general thickness of the Meigs Creek coal in the southern

[1]Geol. Survey Ohio, Vol. V, p. 1,071.

part of the township is given in the following record, taken in a mine on the land of B. F. Conger, which is located in the east central part of Section 33:

		Ft.	In.
Shale, dark, hard		4	--
Coal	*Meigs Creek*	--	7
Shale		--	¼
Coal		1	½
Shale		--	¼
Coal		2	4
Clay, calcareous		2	--

Mr. Conger states that in this locality the coal averages about 4 feet 4 inches in thickness and is very regular. The above records show also the interval from the Meigs Creek member to the Uniontown coal and to other beds of stratigraphic interest. Along the ridge road in the central part of Section 35 the Meigs Creek coal on the outcrop measures 4 feet in thickness, and lies 11 feet above the Sewickley limestone, which occupies an interval of nearly 10 feet. Along the road that leads from Spratt to the ridge south in Section 27 heavy blossoms of the Meigs Creek and Uniontown coals were observed. Outcrop exposures in sections 21, 22, 23, 24, and 25 indicate that the member is 4 feet to 4 feet 6 inches in thickness in most of the area. In places, however, a part of the bed is somewhat shaly in character. The member retains good thickness also in its extension along the ridges from Spratt to Rix Mills, where the bed is reported to be more than 4 feet in thickness, but to have some shaly coal in the lower part of the stratum. On the R. L. Porter land, in Section 4, the Meigs Creek coal lies 55 feet above the Pittsburgh coal, which is 1 foot 10 inches in thickness.

Economic Value

The mine and surface exposures indicate that the Meigs Creek coal is very regular over the entire field in Muskingum County, and that it will average about 4 feet in thickness. Counting 70 per cent available in mining, such a bed will yield nearly 5,040 tons per acre, or 3,225,600 tons per square mile. As nearly as could be computed the productive area will not exceed 20 square miles, but even this gives a large reserve supply of fuel, as but little of the territory has been exhausted. The prevailing rock above the Meigs Creek coal is a dark tough shale, which forms a good roof even where the covering is rather shallow. The floor of the bed is a calcareous clay of only moderate crushing strength. The partings are not especially troublesome, for in most of the field they are only about 1 inch in thickness. Owing to the closely-spaced joints and to the tendency of the coal to split along the stratification planes it shatters in mining to rather small blocks. On the whole the mining conditions are fair.

The general character of the Meigs Creek coal is shown by the

following analysis of a sample taken by R. E. Lamborn and the writer in July, 1917, on the property of Rosa Young, which is located in the northern part of Section 35, Bluerock Township. The sample was cut under heavy covering where the coal was bright and fresh and was only slightly moist. The analysis was made by Prof. D. J. Demorest.

Chemical Analysis and Calorific Value

Ultimate		Proximate	
Carbon	63.25	Moisture	5.16
Hydrogen	5.22	Volatile matter	40.12
Oxygen	12.46	Fixed carbon	41.58
Nitrogen	.86	Ash	13.14
Sulphur	5.07		
Ash	13.14		

Calorific value { 6,429 calories. / 11,572 B. t. u.

Air drying loss of moisture, 2.00 per cent.

Fusion temperature of ash { incipient, 1,125° C. / complete, 1,246° C.

The following partial analysis of the Meigs Creek coal at Rix Mills in Section 3, Rich Hill Township, is taken from Volume V, page 1,072, of this Survey:

Moisture	4.04
Volatile matter	39.59
Fixed carbon	44.58
Ash	11.79
Total	100.00
Sulphur	3.81

The above analyses show that this coal is high in sulphur and ash and somewhat below the standard for Ohio coals in heating value. The sulphur occurs largely in the form of pyrite which gives the ash a grayish or even reddish color. The fusion temperature of the ash, however, is above that of the other thick coals in the county, as the total fluxing impurities are not high. The coal is somewhat oily, but only moderately free-burning. In burning it gives a smoky flame and produces considerable soot. Where unweathered the coal is hard and dense and therefore it withstands handling well. This fuel is considered inferior to the Upper Freeport coal for domestic or for steaming purposes. At present the Meigs Creek coal in Muskingum County is of only minor importance as it is not worked except for local domestic use. In its field, however, in Bluerock, Meigs, and Rich Hill townships it is the only bed with sufficient thickness for regular drift mining and therefore contributes the main supply of fuel.

UPPER SEWICKLEY OR TYSON COAL

The next member in ascending order in the Monongahela formation is the Upper Sewickley or Tyson coal, which has good develop-

ment in the Georges Creek Basin of Maryland, and which has sufficient thickness for mining in a few places in the Pan-handle area of West Virginia, and in Belmont County, Ohio. In Muskingum County a thin shaly coal that appears to be correlative was observed along the road that leads from Sleepy Hollow to the ridge in the eastern part of Section 9, Meigs Township. Its position here is at the base of a thick friable sandstone and about 20 feet above the Meigs Creek or Sewickley coal. The horizon, however, is not marked even by carbonaceous shale at many places in the county as the interval is largely taken either by sandstone or by limestone interbedded with calcareous clay shale.

SEWICKLEY SANDSTONE

Grimsley states:[1]

> Along the eastern outcrop of the Monongahela Series, according to Dr. I. C. White, a massive sandstone frequently comes into the section and cuts out all or a large portion of the Benwood and Uniontown limestones. When present this sandstone overlies the Sewickley coal and was named by Dr. White the Sewickley sandstone. It is well exposed along the Monongahela River between Morgantown and Fairmont, reaching 60 feet in thickness.

In Muskingum County sandstone deposits are rather common, but are distributed over a wide vertical range in the interval between the Meigs Creek or Sewickley and the Uniontown coals. The most persistent deposits, however, lie on or not far above the Meigs Creek member and have a maximum thickness of nearly 50 feet. The position of this sandstone in Muskingum County indicates that it is correlative with the Sewickley member of West Virginia. As the member is not of special interest it will be treated briefly.

The following record taken along the road in the southwestern part of Section 24, Rich Hill Township, shows the Sewickley sandstone and its position with reference to the Meigs Creek coal:

	Ft.
Shale, red	35
Clay shale, weathers red	10
Clay, with limestone nodules	14
Sandstone, thin-bedded, friable, weathers to a coarse sand, *Sewickley*	51
Coal blossom, *Meigs Creek*	4

The Sewickley sandstone is rather persistent and is very thick in most of the southeastern part of Rich Hill Township. In Meigs and Bluerock townships the deposits of Sewickley sandstone are usually somewhat thin and local, and lie a little distance above the Meigs Creek coal, in fact, often well within the body of the Benwood limestone.

BENWOOD LIMESTONE

In the reports of the First Geological Survey of Pennsylvania, the great beds of limestone between the Sewickley and the Uniontown

[1]West Virginia Geol. Survey, Rept. on Ohio, Brooke and Hancock counties, 1906, p. 94.

coals were called the Great Limestone, but in the reports of the Second Survey they were divided by Dr. J. J. Stevenson into two divisions, the Upper, 6 to 18 feet in thickness, lies under the Uniontown coal, and the Lower, which is 50 to 90 feet in thickness, lies above the Sewickley coal. Concerning this Lower division Dr. Stevenson says:[1]

> The lower portion is commonly more or less magnesian, breaks with a smooth surface, which is sometimes lusterless and at other times very bright. This part is employed for the manufacture of cement at many places and is available throughout eastern Washington County. It is the more persistent part of the mass, having been identified in Allegheny County on the Pittsburgh and Steubenville pike. Where exposed to the weather it eventually breaks up into small angular fragments. Its thickness is sometimes fully 50 feet, nearly all of which is limestone. The relative proportion of shale increases northward and in Allegheny County the shale seems to predominate. This portion is wholly non-fossiliferous except in a thin layer at the base. The upper portion contains every variety of limestone, from that pure enough for the manufacture of lime, to that which is utterly worthless for any purpose whatever.
>
> Dr. I. C. White[2] has named the Lower division of the Great Limestone the Benwood, from Benwood, West Virginia, where there are excellent exposures of the rock; and limits the name Uniontown to the Upper division.
>
> In the Ohio County area, where the Uniontown coal is absent, there is found a very persistent bed of green shale at a horizon 80 to 100 feet below the Waynesburg coal, and 80 to 90 feet above the Sewickley. There is a marked contrast in the limestone above and below this shale, but the character of the rock agrees closely with those given by Stevenson for the Lower and Upper divisions of the Great Limestone of Pennsylvania. In the present report this green shale is taken as the dividing horizon between the Upper or Uniontown limestone and the Lower or Benwood.

In Muskingum County both the Uniontown and Benwood limestones are well developed, but their line of division is somewhat uncertain as the Fulton Green shale was not distinctly recognized. However, the well-defined limestone strata of the two members are usually separated by thick beds of variable colored clay shale in which local beds of gray shale and sandstone appear. In general the thickness of the Benwood member in this county is between 30 and 70 feet. In places the basal strata lie on or only a few feet above the Sewickley coal. In most of the area limestone constitutes only a small part of the total thickness; the remainder is clay shale which varies in color from nearly white through pink shades to brownish-red, and which in part is rich in calcareous matter in the form of small nodules. The general structure, however, varies greatly from place to place as the limestone layers are indiscriminately spaced in the body of these clay shales and are uncertain in lateral extension. The maximum thicknesses of the best developed strata of limestone are between 2 and 3 feet, but the usual measurements are less than 1 foot. The material

[1]Second Geol. Survey of Penn., Rept. K, p. 64.

[2]West Virginia Geol. Survey, Report on Ohio, Brooke, and Hancock counties, 1906, p. 91.

is variable in composition as well as in texture and color. The Benwood limestone is regularly present where geologically due in Bluerock, Meigs, and Rich Hill townships.

Near the Bald Knob School, in Section 28, Bluerock Township, the lower part of the Benwood member was well exposed for measurement. The record follows:

		Ft.	In.
Covered		18	--
Limestone, gray, compact	*Benwood*	2	--
Covered		5	6
Shale, gray to flesh color		10	6
Limestone, gray, compact		--	7
Shale and shaly sandstone, gray		8	8
Limestone, gray, compact		1	6
Shale, gray, siliceous		3	4
Clay shale, gray		1	--
Shale, black		--	6
Shale, gray		1	6
Coal blossom, *Meigs Creek*		3	--

About the full thickness of the Benwood limestone is exposed along the road south of Ruraldale in the northern part of Section 35, Bluerock Township. It there measures 63 feet. This member is very prominent on the ridges and knobs north of Ruraldale and also southeast where it passes into Morgan County. In places the interval contains considerably more limestone than shown above, but in other localities it is more largely made up of clay shales.

In Meigs Township the Benwood limestone is very persistent, but it varies greatly in both thickness and structure. The following record taken in the northeastern corner of Section 11 is about typical of the structure of this limestone in the eastern part of the township:

		Ft.	In.
Clay shale, red	*Benwood*	2	3
Limestone		1	6
Clay shale, mottled		5	10
Limestone in several layers		4	6
Clay shale, red and buff, with marly limestone		21	4
Sandstone		--	4
Clay shale, with several beds of limestone		7	--
Shale, gray, parts covered		20	--
Sandstone, shaly		12	--
Coal blossom, *Meigs Creek*		3	--

In the eastern part of Rich Hill Township the lower part of the Benwood member is locally replaced by massive sandstones, but in the central part the full thickness of the beds is represented where the hills rise above their stratigraphic limit. As the sections obtained are about the same as those given they need not be considered.

Economic Value

As a source of limestone the Benwood member in Muskingum County is of small importance as the beds are thin, uncertain, and

are usually widely spaced in the associated clay shales. The material is everywhere somewhat siliceous and in places decidedly so. The color of the limestone varies from dark-blue to light-gray. The rock is rather hard and compact, but on weathering it is reduced to angular pieces with low crushing strength. In some localities considerable quantities of the loose material strewn along the hillsides may be used for road work. The chief value of the member, however, is for its contribution of calcareous matter to the soils. Along this horizon blue grass and legumes thrive and cereals do well. Some of the best fields of alfalfa observed in the county were at this horizon.

FULTON GREEN SHALE

The bright green, finely-laminated stratum of shale, which is well developed in the Wheeling area of West Virginia, and which has been named the Fulton Green shale in the West Virginia reports, was not distinctly recognized in Muskingum County. However, owing to a lack of good exposures, to the thinness of the stratum, and to the extensive slumping and creeping of the red clay shales, the member may have been overlooked. In West Virginia the Fulton member is 2 feet 6 inches to 5 feet in thickness, and is taken as the dividing horizon between the Uniontown and Benwood limestones.

UNIONTOWN LIMESTONE

The Uniontown limestone, the upper division of the Great Limestone of the Second Geological Survey of Pennsylvania, is well represented in local areas in Muskingum County. The member usually consists of several layers of limestone which are separated by clay shale. The proportion of one rock to the other varies considerably both in the vertical section and in the horizontal extension. In the limestone the variation in color is from light or bluish-gray to bright or brownish-yellow, and in composition from a rather pure limestone to one very siliceous and somewhat ferruginous. In the clay shale the range in color is from nearly white to brownish-red, and in composition from ferruginous to highly calcareous material. In Muskingum County the lower limit of the Uniontown and the upper limit of the Benwood members are rather difficult to determine as the limestone strata of the Benwood gradates vertically into red calcareous shale, which passes rather insensibly into the limestone layers of the Uniontown. In parts of the area irregular lenses of gray shale or shaly sandstone are taken as the dividing horizon. From the few sections obtained the interval taken by limestone varies from zero to as much as 20 or 30 feet, but averages only about 10 feet.

In the vicinity of the village of High Hill, in Meigs Township, the Uniontown limestone is several feet in thickness, and is divided into thin to massive beds. The rock is light-blue in color and siliceous in character. Similar deposits were also observed along the ridges in the eastern and southern parts of this township and in the southeastern corner of Bluerock.

UNIONTOWN OR NO. 10 COAL

The Uniontown coal was so named on account of its importance in the vicinity of Uniontown, Fayette County, Pennsylvania, where it is a double bed with good thickness and fair purity. In Muskingum County the member is generally thin, but it is found with considerable regularity in the small area in which it is due. Its position is about 127 feet above the Meigs Creek coal, and 65 feet below the Waynesburg coal. The most conspicuous associated bed is a massive sandstone, which lies either directly or only a few feet above the coal, and which appears to be correlative with the Gilboy sandstone of the West Virginia Survey.

In Rich Hill Township the Uniontown coal is present along the high ridge from the central part of Section 22 to the southeastern part of Section 33. Its elevation is about 1,140 feet above tide. Along the road in the central part of Section 27 the following record was obtained:

		Ft.	In.
Sandstone, *Gilboy*		15	--
Coal blossom	*Upper Uniontown*	1	4
Clay shale		1	6
Coal blossom		2	6
Shale, siliceous		5	--
Clay, gray		5	4
Coal blossom, *Uniontown*		5	2
Shale, gray, siliceous		20	--
Shale, red		4	--
Sandstone, rather massive		24	--
Covered		72	--
Coal blossom, *Meigs Creek*		3	--

The upper division of the Uniontown coal, shown in the above record, is quite local in extent, and was not observed elsewhere in Muskingum County. However, this double structure is rather characteristic of the member in parts of southeastern Ohio, especially along Sunfish Creek east of Woodsfield, and along tributaries of Captina Creek east of Barnesville, in which regions the two coal beds are separated by nearly 10 feet of shale. In Meigs Township this coal is locally present along the main ridge and its spurs that extend from the village of High Hill to Zeno, thence eastward into Noble County, and southward past Young Hickory into Morgan County.

Economic Value

The Uniontown coal adds but little to the fuel resources of Muskingum County as the bed is generally thin, and as the areas with heavy covering are confined to a few square miles. No operating mines and but few prospect openings were observed along the outcrop of the member. The surface exposures indicate that the Uniontown

coal is best developed in the northern part of Meigs and in the southern part of Rich Hill townships, but that even in these areas the bed expands only locally to more than 2 feet in thickness.

GILBOY SANDSTONE

The Gilboy sandstone was named by Dr. I. C. White from prominent exposures in the Gilboy cut of the Baltimore & Ohio Railroad just east from Mannington, Marion County, West Virginia.

In Muskingum County a massive sandstone is very persistent in the interval between the Uniontown and Waynesburg coals. Although the bed in this area is slightly lower in the geological column than that given by Dr. White, it is nevertheless considered correlative, as the vertical range of such members is variable from place to place. The base of the sandstone lies on or within a few feet of the Uniontown coal and the top 15 to 40 feet below the Waynesburg coal. The average thickness of the bed from several measurements is about 35 feet, and the maximum measurement nearly 50 feet. It is a light-gray, coarse-grained sandstone, which is so well cemented that it forms steep slopes along the ridges and knobs. The exposed blocks, however, are only moderately resistant to weathering agencies.

The Gilboy sandstone, 25 to 40 feet in thickness, is present on the knobs of the high ridge that extends from Section 22 to Section 33, Rich Hill Township. It is a very conspicuous bed in the vicinity of High Hill, in Meigs Township, and extends with but few wants southward along this high ridge and its spurs to Zeno, thence eastward into Noble County and southward into Morgan. This sandstone has not been utilized in Muskingum County except in a small way for building stone.

WAYNESBURG LIMESTONE

The Waynesburg limestone, which lies 20 to 35 feet below the Waynesburg coal and not far below the Little Waynesburg coal, is not definitely represented in Muskingum County. Along this horizon, however, the prevailing rock is clay shale, which is highly colored and which is usually rich in calcareous matter in the form of small nodules. No stratified limestone was observed.

LITTLE WAYNESBURG COAL

In the Pennsylvania sections a thin coal bed named the Little Waynesburg by Dr. J. J. Stevenson is locally present 10 to 20 feet below the Waynesburg member. No coal was observed on this horizon in Muskingum County, but its position appears to be indicated by local deposits of gray shale, which are somewhat carbonaceous in character.

WAYNESBURG OR NO. 11 COAL

The Monongahela formation ends with the Waynesburg coal so named by H. D. Rogers from its importance near Waynesburg, Green

County, Pennsylvania, where the bed has been mined for many years. In Muskingum County the member is rather regularly present on some of the highest knobs on the main ridges in central and southern Meigs Township. Its position is 65 feet above the Uniontown coal.

The general stratigraphy of the Waynesburg coal is shown in the following composite record taken along the road and on the farm of F. E. Gallogly, west of High Hill:

	Ft.	In.
Clay shale, red and drab	27	--
Coal, shaly, *Waynesburg*	--	6
Clay shale, red, parts covered	37	--
Sandstone, massive, coarse-grained, *Gilboy*	26	--
Coal blossom, *Uniontown*	2	--

At the crossroads south of Zeno, in Section 23, the blossom of the Waynesburg coal is about 3 feet in thickness and it has much the same measurement in the eastern part of Section 24. In the central part of Section 25 the thickness of the weathered coal on the outcrop is nearly 4 feet and its position approximately 193 feet above the Meigs Creek member.

PERMIAN SYSTEM

DUNKARD SERIES

The rocks of the Dunkard series consist in the main of a succession of buff and gray sandstones, light to brownish-red shales and clay shales, and marly and regularly-bedded limestones. In these a few thin beds of coal are interstratified and many concretions of hematite are irregularly distributed. Owing to the lack of thick coal beds it was formerly called the Upper Barren Coal Measures. The series is generally divided into two formations known as the Green and Washington. Of these only the lower part of the Washington formation is represented in Muskingum County.

WASHINGTON FORMATION

The Washington formation, the lower division of the Dunkard series, begins with the Cassville Plant shale which is the roof of the Waynesburg coal and ends with the Upper Washington limestone. The total thickness of rocks of this formation in Muskingum County is less than 60 feet and their extent is very limited as the beds are present only on a few of the high knobs along the main ridges in central and southern Meigs Township. The members will be treated in regular order beginning with the oldest.

CASSVILLE PLANT SHALE

The Cassville, the basal member of the Washington formation, lies directly above the Waynesburg coal of the Monongahela formation

and is usually between 2 and 10 feet in thickness. It is a dark or bluish-gray shale, which is usually rich in plant fossils. The member was not definitely recognized in Muskingum County.

ELM GROVE LIMESTONE

The Elm Grove limestone, so named from exposures near the village of Elm Grove on Wheeling Creek in Ohio County, West Virginia, is a dark-blue rock of fresh-water origin and of low purity. Its position usually is only a few feet above the Waynesburg coal. In Muskingum County two layers of blue limestone, which are considered correlative with the West Virginia deposits, were observed on the knob near High Hill in Section 4, Meigs Township. The record obtained follows:

		Ft.	In.
Sandstone, shaly		3	--
Clay shale, red and yellow		7	--
Shale, gray, with sandstone layers	*Waynesburg*	5	--
Sandstone, shaly, gray	*Waynesburg*	5	--
Clay shale, red		4	--
Limestone, blue	*Elm Grove*	--	6
Clay shale	*Elm Grove*	1	2
Limestone, blue	*Elm Grove*	--	4
Clay shale, red and drab		27	--
Coal, shaly, *Waynesburg*		--	6

The interval at this place is considerably greater than it is in the West Virginia areas, but this may be only a local condition. The Elm Grove member was not observed in the southern part of Meigs Township.

WAYNESBURG SANDSTONE

On a few of the high knobs in Meigs Township deposits of sandstone which appear to be correlative with the Waynesburg sandstone were observed 20 to 30 feet above the Waynesburg coal. The rock is somewhat shaly in character and gray or buff in color. The deposits are 5 to 20 feet in thickness.

CHAPTER VI

SEARCH FOR OIL AND GAS

General Statement

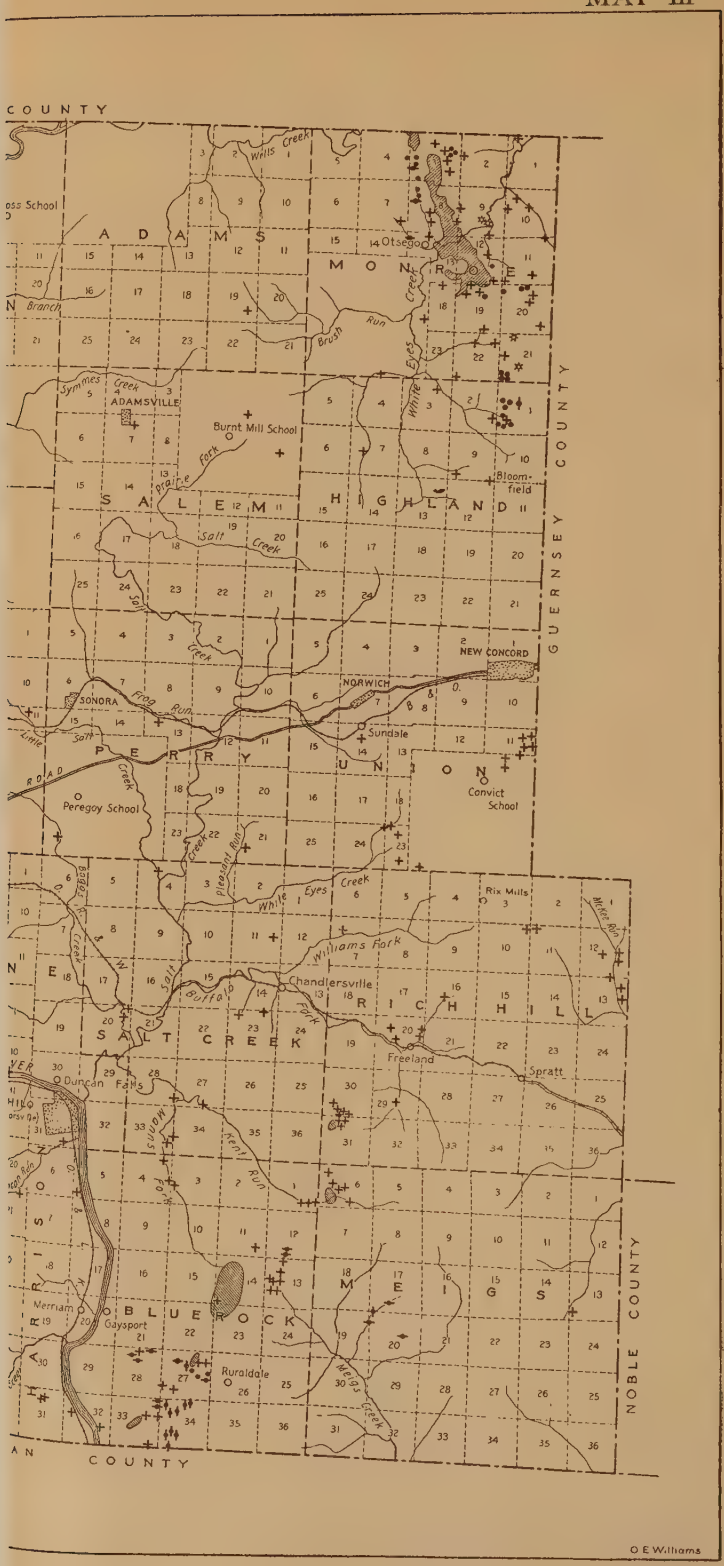
Following the discovery of oil near Titusville, Pennsylvania, in 1859, and near Marietta, Ohio, in 1860, the search for this natural rock product began over wide areas, especially in the coal formations in these two states. In Muskingum County prospecting began near the village of Ruraldale, in Bluerock Township, at least as early as 1864. Oil was found, hence drilling became very active in the following year. The wells were drilled by means of the spring pole and treadle, and but few of them exceeded 200 feet in depth. Since these early results in the shallow sands, drilling has continued in a somewhat desultory way, but the tools are yet active in the western part of the county. Aside from this small pool near Ruraldale, others have been developed near Otsego and Bloomfield, near Cannelville and Roseville, near Fultonham, near Gratiot, and near Nashport and Black Run. In all, in the autumn of 1917, about 1,100 wells had been drilled in Muskingum County, and of these more than 800 have yielded rewards for the labor and money expended. In 1917 nearly 375 wells were producing either oil or gas in commercial quantities, and the yield was approximately 2,000 barrels of oil and 5,000,000 cubic feet of gas per day. Although a wide vertical column has been exploited by the drill only three productive sands, the "Clinton," the Berea, and the Cow Run, have been found.

"CLINTON SAND"

The "Clinton sand" of the oil driller is now generally regarded by geologists as an interstratified bed of sandstone in shales of Medina age.[1] As this stratum nowhere comes to the surface in Ohio, its stratigraphic relations are obtained only from well records, from which the division between the Medina and the overlying formations of the Silurian is somewhat uncertain. The "Clinton sand" is of wide extent in Ohio, as it has been located by the drill in a broad belt extending from Ashtabula County to Cleveland, Wooster, Mt. Vernon, Newark, Lancaster, McArthur, and Jackson in Jackson County. From Jackson to the Ohio River only traces of the sand have so far been detected. In central Ohio the "Clinton sand" becomes thin, patchy, and then wanting in western Licking and Fairfield counties, but it extends eastward into Coshocton, Muskingum, and Morgan counties as far as the search has extended. In Muskingum County the average thickness of the

[1]Bownocker, J. A., Economic Geology, Vol. VI, p. 49.

SEARCH FOR OIL AND GAS IN MUSKINGUM COUNTY


COUNTY
ADAMS
MONROE
SALEM
HIGHLAND
PERRY
UNION
SALT CREEK
RICH HILL
MEIGS
BLUE ROCK
GUERNSEY COUNTY
NOBLE COUNTY
COUNTY
Wills Creek
Otsego
Brush Run
White Eyes Creek
Symmes Creek
ADAMSVILLE
Burnt Mill School
Prairie Fork
Bloomfield
Salt Creek
NEW CONCORD
NORWICH
SONORA
Frog Run
Little Salt Creek
Sundale
Convict School
Peregoy School
Pleasant Run
Rix Mills
Bigger Run
Williams Fork
Chandlersville
Buffalo Fork
Duncan Falls
Freeland
Spratt
Morris Run
Kent Run
Merriam
Gaysport
Ruraldale
Meigs Creek
O E Williams

bed, from a large number of records, is about 43 feet, and the maximum measurement recorded is 73 feet. In a few wells the sand was wanting, or nearly so, but, on the whole, it is very steady in both thickness and extent. This rock is fine-grained and in most places rather hard. In some localities the texture is so close that it forms a poor container for either oil or gas. It varies in color from white through shades of gray and pink to red. Although production is found in both the light and colored varieties, it occurs in this area, as elsewhere, more frequently in the lighter-colored sands. In most of the wells only one pay streak is found in the sand, but in some two or even three pay streaks are reported. In this area the "Clinton sand" is everywhere reported free from water, which is characteristic of the stratum in other parts of Ohio.

In its extension eastward the expansion of the interval from the top of the "Clinton sand" to the top of the Berea sandstone is rapid, and amounts to 35 feet to the mile. This measurement was taken from wells extending along lines from Liberty Township, Licking County, to Adams Mills, Muskingum County; from Granville, Licking County, to Rock Cut, Muskingum County; from Buckeye Lake, Fairfield County, to Perry Township, Muskingum County; and from Rushville, Fairfield County, to Crooksville, Perry County. This expansion is very constant in the area covered and is distributed about as follows:

Thickening of Berea sandstone	1.4	feet per mile east.
" " Bedford and Ohio shales	21.4	" " " "
" " Devonian and Silurian limestones	12.1	" " " "
" " Shale between Silurian limestone and "Clinton sand"	0.1	" " " "
Thickening of total strata	35.0	" " " "

From an average of the results from several lines drawn from north to south across the same area, the expansion of the Berea-"Clinton" interval amounts to only .74 feet per mile south. This change is also rather constant when local variations are omitted. These expansions probably continue eastward and must be considered by those desiring to drill east of the present border wells. The depth of the "Clinton sand" at any given location east of present drilling may be closely approximated by use of these figures, for the depth to the Berea sandstone is commonly known. To the surface-Berea interval add the Berea-"Clinton" interval in the first western well. To this result add 35 feet for every mile the new location is east of the known "Clinton" well, and add or subtract, as the case may require, .74 feet for every mile the new location is south or north of the "Clinton" well. For example, it is desired to drill a well at Otsego in Monroe Township. Here the surface-Berea interval is about 1,000 feet. To this the Berea-"Clinton" interval of 2,725 feet in the H. A. Sharp well at Adams

Mills is added. Otsego is 9.9 miles east and 2.2 miles south of the Sharp well, hence the expansion of the interval is approximately (9.9 x 35)+(2.2 x .74)=348 feet. Adding these results the calculated depth of the "Clinton sand" at Otsego is nearly 4,073 feet. If other "Clinton" wells are used as a basis, slightly different results are obtained, owing to local variations.

From a rough survey the "Clinton sand" in Muskingum County shows no decided variation in structure, but does show local modifications. These results are also confirmed by oil geologists who have made more careful measurements. When wide areas are considered both the eastern and the southern dips of the sand are rather uniform, and the former is far in excess of that of the coal formation strata. Regarding the circulation and accumulation of oil and gas in the "Clinton sand", Bownocker states:[1]

> The closed or rock pressure of gas wells is commonly regarded as due to the weight of a column of water; that is, to hydrostatic pressure. Occasionally gas wells in the Bremen field register 700 pounds or even more to the square inch, and yet the fuel comes from a formation that is free or nearly so from water and that is imbedded in shales that are impervious. The same is true in the great gas fields in central Ohio. These facts demonstrate that water is not the cause, or even a factor, in the rock pressure of gas in the Clinton sand.
>
> Gas, when found, is nearly always in the higher parts of the formation, that is, along its western border, and oil at greater depths to the east. It is a common theory that oil rests on the surface of salt water and rises or falls with this liquid. That cannot apply in the Bremen field for the reason that little or no brine is present, and it is a reasonable assumption that the oil accumulates in the depressions where the Clinton sand is sufficiently open textured to store it.

SHALES BETWEEN THE "CLINTON SAND" AND THE "BIG LIME"

In the area under consideration the main body of these shales is usually light-gray or bluish-gray in color. In places, however, some layers with a pink or a red color are also present. Parts of these shales are so soft and yielding that they cave badly in drilling. In most areas 10 to 40 feet, or on the average 26 feet, above the "Clinton sand", hard layers of rock termed "shells" by the drillers are encountered. The average thickness of these is about 22 feet and the maximum record is 56 feet. In some areas these resistant beds are wanting. In this county the thickness of the shales and "shells" between the "Clinton sand" and the base of the great Silurian limestones varies from 50 to 225 feet, but averages nearly 139 feet. This interval thickens slightly to the eastward. How much of these shales are of Medina age is not definitely known, but probably the greater part. The texture of the material is such that it makes an impervious covering for the sand in which the oil and gas gradually accumulated.

[1]Bownocker, J. A., Geol. Survey Ohio, 4th Ser., Bull. 12, p. 24.

"BIG LIME"

The term "Big Lime" is applied by drillers working in "Clinton sand" fields to a great series of limestones and dolomites which belong to the Silurian and Devonian periods, and which are always present in massive development in central and northern Ohio, and, in fact, as far east as the drill has been able to reach the horizon. Many of these beds appear at the surface in western Ohio and far to the east in Virginia, Pennsylvania, and New York. From the work of Dr. J. A. Bownocker and others, the lowest limestone in this group appears to be the Brassfield and the highest the Delaware. These beds expand rapidly towards the east; the thickness is about 730 feet near Alexandria in Licking County, 1,100 feet near Adams Mills in Muskingum, 625 feet near Baltimore in Fairfield, and 950 feet near Crooksville in Perry. As previously shown, this expansion to the east amounts to 12.1 feet per mile. In Muskingum County the maximum and minimum measurements of the "Big Lime" are 1,120 and 810 feet and the average thickness 965 feet. To the driller but few changes or "breaks" in this great mass of limestone are evident. Some state, however, that about 200 feet of the upper portion drills somewhat harder and more gritty than the main body of the material, and that along horizons where water is present thin beds of impure sandstone or calcareous shale are found. From this it would appear that the water either circulates within the thin beds of sandstone or within porous limestones at the contact of these rocks with the shales. Water occurs with considerable regularity in the "Big lime", but the horizons are scarcely correlative from place to place. In Muskingum County it occurs the most frequently at depths of approximately 685, 740, and 790 feet below the top of the mass. Showings of oil or gas are also occasionally struck at these levels. In some localities water is present at only one horizon, whereas in others it is found at two or even three levels. The flow of water also varies considerably from place to place. That from the upper horizon is usually less than that from the lower levels. These flows of water are seldom serious, and in some cases the quantity produced is only about that required to do the drilling. The dolomites are softer than the limestones.

The "Big lime" of the drillers working in "Clinton sand" fields must not be confused with the "Big lime" of the drillers working in the Berea and higher sand fields, for the latter is the Maxville limestone of Ohio or the Greenbriar of West Virginia and lies about 2,080 feet above the former.

OHIO AND BEDFORD SHALES

In ascending order the next formation of importance is the great Ohio shale, which also belongs to the Devonian system. In Ohio these rocks extend in an unbroken sheet east of a line drawn from Sandusky,

past Bucyrus, Delaware, Columbus, and Greenfield to Buena Vista. The main body of these shales has a dark-gray or nearly black color, but some layers vary towards buff or greenish shades. The material is decidedly carbonaceous and argillaceous in composition. Small concretions of pyrite are common throughout the mass, and large concretions of siliceous, ferrous carbonate are in places abundant in the lower part of the formation. Concerning production Dr. Bownocker states:[1]

> The Ohio shales have long been a source of gas along the lake shore. Usually a well supplies heat and light for a residence, and occasionally for several, but the supply is never large. The gas is not found at any one horizon and hence the depth varies. In central Ohio the shales contain less fuel, and are not a source of gas in a commercial way. In Pennsylvania this great formation contains a number of important oil and gas rocks, such as the Bradford, McDonald, and Gordon sands. Westward these thin and disappear or practically so, by the time the Ohio River is reached. Many wells for one or the other have been sunk in eastern Ohio, but the result in every case has been failure.

The Ohio shale is overlain by the Bedford shale, which belongs in the Mississippian system, and which extends upward to the Berea sandstone. The Bedford shale varies in color from dark-gray, through light-gray, and green to pink or nearly red, and in composition from argillaceous shale through siliceous shale to shaly sandstone. The upper portion is usually more clay-like and highly colored than the lower and is, therefore, more frequently distinguished by the drillers. The contact between the Bedford and Ohio formations is seldom defined in well records.

The thickness of these two formations, the Bedford and Ohio, expands rapidly to the east, and as has been previously shown it increases 21.4 feet per mile, from Alexandria in Licking County and Baltimore in Fairfield, on the west, to Adams Mills in Muskingum and Crooksville in Perry on the east. The expansion to the south is very small. In Muskingum County the average thickness of these two formations is 1,321 feet, and the minimum and maximum measurements are 1,180 and 1,500 feet. No sands or production is recorded in either formation. These shales, of course, are free from water.

The Search for the "Clinton Sand"

In Muskingum County, to the autumn of 1917, the "Clinton sand" had been reached by the drill 155 times, and it was the rock desired in 10 wells then in process of drilling. Of those completed, 115 produced oil or gas in commercial quantities, whereas 40 gave no rewards for the labor and money expended. The number of gas wells is small. With the exception of a few scattered tests the work has been confined to the area west of the Muskingum River and Moxahala

[1]Geol. Survey Ohio, 4th Ser., Bull. 12, p. 28.

Creek. The trend of the main production extends from Nickel Valley Run in sections 23 and 24, Pike Township, Coshocton County, southward past the villages of Black Run and Gratiot, Muskingum County, to Mt. Perry, Perry County. In fact, these pools in Muskingum, Licking, and Coshocton counties appear to be only connecting links between the Wooster and Shawnee pools, or to be a part of the great productive belt that extends from Cleveland to Vinton County.

In Muskingum County, the most northern pool of oil, which is small, as it contains only six wells, is found in the northwestern corner of Jackson Township. The largest productive field by far is in northwestern Licking Township, with a small extension northward into southwestern Jackson Township, and westward into Hanover Township, Licking County. More than 80 producing wells are present in this area and others are in process of drilling. The next pool of importance along this belt is in Hopewell Township, Licking County, with a small outlying area south of Gratiot in Hopewell Township, Muskingum County.

Another belt along which there is scattered production extends from near Trinway to Fultonham. These small pools are about 6 miles east of the more extensive fields in the western part of the county, and the general trend of the two is about parallel. Near Trinway only two wells have been drilled; one is producing oil and the other gas. Small quantities of gas have been found in several tests drilled in the central part of Muskingum Township. The most productive area by far along this belt is in the vicinity of Fultonham, where both oil and gas are produced in commercial quantities. This field, however, has passed its zenith, and many of the wells are now abandoned. So far, the tests drilled east of this belt in Cass, Madison, Washington, and Perry townships, have been failures.

Jackson Township.—In Jackson Township, which lies in the northwestern part of the county, 15 "Clinton" wells have so far been drilled. In 1917, 8 of these were producing oil, but the yields were not large. The main production is in the northwestern part where the Ohio Cities Gas Co. obtained the following results: In Section 3 one well with a showing of oil, on the land of Lewis Ashcraft, one producer on the farm of Jacob Ashcraft, and one on that of Jackson Drumm; in Section 4 two producers on the land of Robert Ashcraft, and in Section 5 two producers on the property of George W. Crawford. The record of the Robert Ashcraft well, furnished by the Ohio Cities Gas Co., follows:

	Thickness in feet.	To top of formation.
Drive pipe	50	-----
Berea sandstone	15	650
Bedford and *Ohio* shales	1,220	665
"Big lime"	895	1,885
Shale	125	2,780

	Thickness in feet.	To top of formation.
"Shells"	14	2,905
Shale	42	2,919
"Clinton sand"	50	2,961

The records of other wells in this locality are much the same. Water was found in the "Big lime" at depths of approximately 2,510 and 2,620 feet. In the G. W. Crawford well No. 1 the Berea sandstone, 20 feet in thickness, was reached at a depth of 600 feet; the "Big lime," 929 feet in thickness, at 1,820 feet; and the "Clinton sand," 61 feet in thickness, at 2,893 feet. Two flows of water were found in the "Big lime," one at a depth of 2,405 feet and the other at 2,440 feet.

The Ohio-Rochester Co. drilled a test on the farm of Alva Fairall, in the southern part of Section 7, but only a showing of oil was secured. A small well, now abandoned, was drilled by the Ohio Cities Gas Co. on the property of Lansing Yingling in the southern part of Section 14, and an unproductive test on the land of Samuel Divan in the northern part of Section 16. West of the cemetery in Section 19, a local company from Frazeysburg drilled a "Clinton" well on the farm of W. Hamilton. Neither oil nor gas was secured. Unfavorable results were also obtained by the Ohio Cities Gas Co. in a test on the land of J. H. Frazier in the northwestern part of Section 23. The record of the Frazier well No. 1 follows:

	Thickness in feet.	To top of formation.
Berea sandstone	20	650
Bedford and *Ohio* shales	1,245	670
"Big lime"	956	1,915
Shale	20	2,871
"Shells"	25	2,891
Shale	94	2,916
"Clinton sand"	44	3,010

The total depth of this well is 3,069 feet, and that of the gravel, before the bed rock of the old Newark River was found, is 180 feet. Water was struck at a depth of 2,578 feet, or in the "Big lime" 663 feet from its top. Production was obtained by the Ohio Cities Gas Co. in one test drilled on the land of John Fleming, and in another on that of Margaret Fleming in Section 25. In the northern part of this section a small well, now abandoned, was drilled by the Heisey Oil & Gas Co. on the farm of W. L. Ridenbaugh.

Adjacent Territory.—A small productive "Clinton" area is also present along Nickel Valley Run in sections 23 and 24, Pike Township, Coshocton County. The Spindler Oil Co. has two producing wells on the property of Clyde McKee and one on that of J. Wolfram; the Leonard Petroleum Co. one on that of Lydia McKee, and the Ohio Cities Gas Co. three on the land of Charles Kilpatrick. Other wells were also being drilled in the fall of 1917. In the Charles Kilpatrick well No. 1

the "Big lime," 995 feet in thickness, was reached at 1,910 feet, and the "Clinton sand", 53 feet in thickness, at 2,997 feet. Another small pool is also present south of Perryton in Perry Township, Licking County. The record of the Leatherman well No. 2, furnished by the Ohio Cities Gas Co., follows:

	Thickness in feet.	To top of formation.
Berea sandstone	24	715
Bedford and *Ohio* shales	1,156	739
"Big lime"	923	1,895
Shale	129	2,818
"Clinton sand"	50	2,947

Licking Township.—Licking Township is by far the largest producer of oil in Muskingum County at the present time. The field known as the Black Run lies in the northwestern part of the area, and extends northward from the Licking River to the township line, and eastward to the ridge known as the Highlands. When the region was visited in the fall of 1917, it contained 75 producing wells and only 4 dry holes. Further, a number of rigs were drilling in promising territory. The initial production of the wells was from 25 to 250 barrels per day, and the settled production after 6 months from 10 to 50 barrels. This field was opened in 1915 and had not yet reached its maximum, as drilling was still very active.

In the northwestern corner of the township the Ohio Cities Gas Co. had drilled two producing wells on the farm of R. L. Shoemaker, five on that of L. S. Romine, two on that of J. F. Stitt, and two on that of W. W. Stump. The record of the Romine well No. 1, furnished by the Ohio Cities Gas Co., is given below:

	Thickness in feet.	To top of formation.
Gravel and sand	215	-----
Shale and sandstone	453	215
Berea sandstone	12	668
Bedford and *Ohio* shales	1,190	680
"Big lime"	893	1,870
Shale	124	2,763
"Shells"	5	2,887
Shale	35	2,892
"Clinton sand"	50	2,927

The well head is nearly 780 feet above tide and the location is in the old Newark Valley, to which is attributed the great thickness of gravel and sand. Other wells in this locality show from 87 to 227 feet of such material before bed rock is reached. The main body of the pool is south of this along the old channel that extends from the Licking to the old Newark valleys. The Ohio Cities Gas Co. has three producing wells on the farm of G. L. Shipley, ten on that of G. W. Madden, and five on that of L. Montgomery; the Edward H. Everett

Co. has 18 producing wells, and others in process of drilling, on the property of C. O'Bannon. The record of the Madden well No. 6 is given below:

	Thickness in feet.	To top of formation.
Gravel and sand	75	-----
Shale and sandstone	610	75
Berea sandstone	15	685
Bedford and *Ohio* shales	1,215	700
"Big lime"	920	1,915
Shale	85	2,835
"Shells"	15	2,920
Shale	18	2,935
"Clinton sand"	60	2,953

Water was encountered at a depth from the surface of 2,545 feet, or from the top of the "Big lime" of 630 feet. The covering on the bed rock of this old valley is stated to vary from 60 to 115 feet. On the O'Bannon property the Edward H. Everett Co. reports that the gravel and sand have a thickness of 74 feet in well No. 13, 52 feet in well No. 14, 59 feet in well No. 15, and 64 feet in well No. 16, and that the Berea and the "Clinton sand" were reached respectively at 688 and 2,969 feet in well No. 13, 722 and 2,998 feet in well No. 14, 670 and 2,941 feet in well No. 15, and 705 and 2,987 feet in well No. 16. These wells are all good producers and the limits of the area are not yet defined. The Boone wells of the Ohio Cities Gas Co. are located along the ridge 2 miles northwest of Nashport, and east of this along the valley that extends northward from Nashport to the old Newark Valley. In the fall of 1917, in this area, 20 wells were producing oil in commercial quantities and 2 wells were in process of drilling. The record of the well drilled on the right-of-way of the old canal follows:

	Thickness in feet.	To top of formation.
Sand and gravel	77	-----
Shale and sandstone	604	77
Berea sandstone	17	681
Bedford and *Ohio* shales	1,256	698
"Big lime"	911	1,954
Shale	100	2,865
"Shells"	16	2,965
Shale	20	2,981
"Clinton sand"	59	3,001

Along the ridge 1½ miles north of Nashport the Ohio Cities Gas Co., in the fall of 1917, had two producers and one location on the land of John Finan, two producers on the tract of H. B. Fleming, two producers and one dry hole on the farm of Charles Fleming, one producer on that of Findley Fleming, and one producer and one location on that of A. Montgomery. Since then other wells with good yields of oil have been drilled in this locality. The test by this company on the farm of

H. Van Voorhis, which is located one-half mile west of Nashport, gave neither oil nor gas in commercial quantity. South of the Licking River in Licking Township only two attempts had been made to the fall of 1917 to obtain production in the "Clinton sand," but both of these were failures. The work was done by the Ohio Cities Gas Co. on the farms of W. T. Gearhart and Frank Perry. The record of the Gearhart well follows:

	Thickness in feet.	To top of formation.
Berea sandstone	36	740
Bedford and *Ohio* shales	1,224	776
"Big lime"	900	2,000
Shale and "shells"	139	2,900
"Clinton sand"	35	3,039

Adjacent Territory.—In Hanover Township, Licking County, a few small wells are located just west of the Black Run pool. The most productive area, however, is near Toboso, where a number of wells are present both north and south of the Licking River. On the northern extension of this pool, M. F. Whitehill has four wells on the V. K. Herendeen property, which is located north of the village of Boston and in the old Newark Valley. The thickness of the gravel and sand on the rock floor of this old abandoned waterway is of interest as it is reported to be 280 feet in the No. 3 well. In this test the Berea sandstone was found at 680 feet, the "Big lime" at 1,852, and the "Clinton sand" at 2,897 feet.

Hopewell Township.—In Hopewell Township 19 wells have been drilled to the "Clinton sand," but only 8 have produced oil in paying quantities, and 2 of these are now abandoned. This small pool is located south of Gratiot in Section 7, south, and it has passed its zenith. The most northern test in the area was drilled by the Ohio Cities Gas Co. on the farm of J. L. Varner, which is located in Section 5, south of the village of Cottage Hill. The record furnished by this company follows:

	Thickness in feet.	To top of formation.
Berea sandstone	10	815
Bedford and *Ohio* shales	1,278	825
"Big lime"	810	2,103
Shale	48	2,913
"Shells"	22	2,961
Shale	132	2,983
"Clinton sand"	23	3,115

At this place the "Clinton sand" was not only thin, but broken, hence no production was secured. Water was struck at a depth of 2,733 feet, or in the "Big lime" 630 feet from its top. The Ohio Fuel Supply Co. failed to secure more than a showing of gas in the test drilled on the land of E. T. Smith in Section 8, north, and John Leonard was not rewarded for his work in the well on the land of Joseph Corson, which

is located just west of Mt. Sterling. Unfavorable results were also obtained in two tests drilled by the Ohio Cities Gas Co. on the farm of Mrs. Edith Day, which is located in the northern part of Section 6. One well was drilled near the church at Gratiot and the other just south of the National Road about 1 mile west of the village. Small oil production was obtained by the Ohio Fuel Supply Co. in two wells, now abandoned, on the farm of Robert Hamilton, in Section 7. Just east of this the Planet Oil Co. has two producing wells and one dry hole on the farm of A. L. Ankrum. In this pool four wells with good yields of oil, and one with only a showing, was drilled by the Ohio Cities Gas Co. on the land of Johnson and Cone. The record of the No. 1 well on this property follows:

	Thickness in feet.	To top of formation.
Berea sandstone	45	800
Bedford and *Ohio* shales	1,205	845
"Big lime"	870	2,050
Shale	93	2,920
"Shells"	10	3,013
Shale	12	3,023
"Clinton sand"	38	3,035

Water was found at a depth of 2,630 feet. The wellhead is 60 feet below the Lower Mercer limestone and has an elevation of 920 feet above tide. A well with only a showing of oil was also drilled by the Ohio Cities Gas Co. on the land of Pearl Harkness in the central part of Section 7. Three unproductive tests were drilled in Section 8, one on the land of Howard Chapman by the Ohio Fuel Supply Co., one on that of Mrs. C. C. Zartman by a local company, and one on the tract of John Shaffer by the Ohio Cities Gas Co.

Adjacent Territory.—A large pool of oil is situated about 2 miles north of Gratiot in Hopewell Township, Licking County. In the fall of 1917 it contained 19 producing wells, 8 dry holes and 4 locations with rigs drilling. The largest well in the area is on the John S. Loughman property, and it had an initial production of 418 barrels. In Section 12 the Ohio Cities Gas Co. had two producers on the land of J. D. Gard, five producers on that of John S. Loughman, one location on that of C. L. Loughman, one location on the farm of Scott Kreiger, and one dry hole on that of Sarah Iden; and the Planet Oil Co. had two producers on the property of E. L. Kreiger. The record of the J. D. Gard well is given below:

	Thickness in feet.	To top of formation.
Berea sandstone	8	940
Bedford and *Ohio* shales	1,182	948
"Big lime"	895	2,130
Shale	51	3,025
"Shells"	33	3,076
Shale	56	3,109
"Clinton sand"	45	3,165

South of this, in Section 19, the Planet Oil Co. had three producers on the farm of E. L. Kreiger, and one with a showing of oil on that of John R. Humphrey; and the Ohio Cities Gas Co. had three producers and two locations on land of K. A. Porter, and two wells with showings of oil on that of John R. Humphrey. In the northeastern part of Section 23, the Arkansas Heat, Light, and Fuel Co. had one pumping well on the land of J. E. Armstrong. In Section 20 a showing of oil was secured by the Ohio Cities Gas Co. on the farm of Levi Cook, and a showing of both oil and gas was found by the Carter Oil Co. on the tract of Edward Coe. Two pumping wells on the land of John Fisher, and one on that of Susanna Iden, in Section 11, are controlled by the Ohio Cities Gas Co., who also drilled an unproductive test on the property of Leonidas Hanley in the southern part of Section 10, and another on that of E. H. Duncan in the central part of Section 18.

In Bowling Green Township, Licking County, the Ohio Cities Gas Co. drilled a dry hole in the southeastern part of Section 1 on the land of Lewis McMullin, an oil producer in the central part of Section 12 on the property of George Rankin, and a gas producer, now abandoned, in the southeastern part of Section 13 on the farm of Oscar Axline. In the northern part of Section 6, Madison Township, Perry County, a gas well with an initial production of nearly 2,000,000 cubic feet, now controlled by the Ohio Fuel Supply Co., was drilled by Bremen parties on the farm of Mrs. Oscar Baird. This is the largest gas well, and in fact the only one of importance, along this belt of production which extends from Nickel Valley Run in Coshocton County to Mt. Perry in Perry County.

Cass Township.—Up to the fall of 1917 only three "Clinton" wells had been drilled in Cass Township; two of these gave rewards for the labor and money invested. On the farm of William Hamilton, in the southeastern part of Section 4, Ralph Brothers, of New Lexington, drilled to the "Clinton sand" in the spring of 1916, and secured a good gas producer. The initial flow is reported to have been nearly 3,000,000 cubic feet, and the settled production in the fall of 1917 about 1,500,000 cubic feet. The sand was reached at a depth of 3,264 feet, and is stated to be hard and fine. Southeast of this, in Section 8, Scott & Endsley found oil in the "Clinton sand" on the farm of C. B. Faucett. The production is small. The record of this test, furnished by the Ohio Cities Gas Co., is given below:

	Thickness in feet.	To top of formation.
Sand and gravel	166	-----
Shale and sandstone	609	166
Berea sandstone	20	775
Bedford and *Ohio* shales	1,360	795
"Big lime"	1,088	2,155
Shale and "shells"	77	3,243
"Clinton sand"	58	3,320

The first pay was found from 3,330 to 3,335, and the second pay from 3,349 to 3,354 feet. The elevation of the wellhead is about 765 feet above tide, and the great thickness of the gravel and sand is accounted for by the position of the well in the old Newark Valley.

One of the most eastern deep wells in the county was drilled by the Canadian-Ohio Oil Co., on the farm of H. A. Sharp, which is located one-half mile west of Adams Mills. Only a showing of gas was secured. The record furnished by the Ohio Cities Gas Company follows:

	Thickness in feet.	To top of formation.
Gravel and sand	150	-----
Shale and sandstone	650	150
Berea sandstone	30	800
Bedford and *Ohio* shales	1,470	830
"Big lime"	1,110	2,300
Shale and "shells"	115	3,410
"Clinton sand"	41	3,525
Medina red shale	16	3,566

In this test water was found in the "Big lime" at depths of 3,150 and 3,190 feet. Just north of Adams Mills, but in Coshocton County, the "Clinton sand" was also tested by the Canadian-Ohio Oil Co. on the land of P. S. Gray, and a small quantity of oil secured. The log of the Gray well is practically the same as that of the Sharp well given above.

Muskingum Township.—In Muskingum Township, to the autumn of 1917, seven wells had been drilled to the "Clinton sand," but so far the results have been rather discouraging, as only small quantities of gas or oil have been found. In the southwestern part of Section 7, on the W. S. Riley property, the Oil Trust, Ltd., London, England, drilled a test which gave a showing of a very thick oil. This company also drilled an unproductive well on the farm of C. Gorsuch. A good showing of gas was obtained by Scott & Endsley in a well on the farm of R. W. Woodruff, which is located in the northeastern part of Section 14. The log of this test, furnished by the Ohio Cities Gas Co., follows:

	Thickness in feet.	To top of formation.
Clay and sand	48	-----
Shale and sandstone	782	48
Berea sandstone	18	830
Bedford and *Ohio* shales	1,384	848
"Big lime"	978	2,232
Shale	102	3,210
"Shells"	25	3,312
Shale	46	3,337
"Clinton sand"	28	3,383

The "Big lime" contained water at a depth of 3,085 feet. Scott & Endsley secured a small flow of gas, which was used for a time locally, in a well drilled in the central part of Section 13 on the farm of George

Shaw. A test 3,447 feet in depth, drilled in 1917 on this property by the Ohio Fuel Supply Co., yielded an initial open flow of 200,000 cubic feet of gas with a rock pressure of 795 pounds. No sand was found by Scott & Endsley in the test drilled on the Josephine Cole land in the northeastern part of Section 13. The drill struck the top of the "Big lime" at a depth of 2,264 feet and the bottom at 3,285 feet, but failed to find any sand, although it descended to a depth of 3,625 feet. The most eastern well in this township is that on the Thomas Bainter land, which is located in a hollow south of the Muskingum River, or about one-half mile north of the Sandy Ridge School. This test was drilled by the Ohio Petroleum Co. and was unproductive. For the following record of this well the Survey is indebted to the Medina Gas and Fuel Co.

	Thickness in feet.	To top of formation.
Berea sandstone	20	828
Bedford and *Ohio* shales	1,427	848
"Big lime"	1,012	2,275
Shale and "shells"	228	3,287
"Clinton sand"	10	3,515

Falls Township.—In Falls Township the "Clinton sand" has been reached twice by the drill, but it yielded neither oil nor gas in paying quantities. One test was made by the Canadian Oil and Gas Co. on the property of William Merkle. This well is located near the west bank of Big Run, about three-fourths mile from its mouth. The record furnished by the Ohio Cities Gas Co. follows:

	Thickness in feet.	To top of formation.
Berea sandstone	12	770
Bedford and *Ohio* shales	1,348	782
"Big lime"	995	2,130
Shale and "shells"	147	3,125
"Clinton sand"	32	3,272
Medina shale	12	3,304

A "Clinton" well was drilled by the Chicago-Zanesville Oil and Gas Co. on the property of Musselman & Sutton, which is located about 1 mile north of the Licking River, and nearly the same distance east of Dillon Falls. A showing of both oil and gas was found.[1] An attempt was made to reach the "Clinton sand" at the plant of the American Encaustic Tiling Co., Zanesville, but the drill stopped in the "Big lime" at a depth of 3,220 feet. The Berea was struck at 850 feet.

Springfield Township.—The only test of the "Clinton sand" in Springfield Township was made by the Zane Co. in 1917, in the northwestern part of Section 18, on the J. E. Burgess property. The well gave an initial flow of 600,000 cubic feet of gas per day.

[1]For the record of the Musselman-Sutton well see Geol. Survey Ohio, 4th Ser., Bull. 12, p. 35.

Newton Township.—The most southern production in the "Clinton sand" in Muskingum County is in the vicinity of Fultonham, in Newton Township, in which area 19 wells have been completed, and one was in process of drilling in the fall of 1917. The field, now past its maximum, is small, but yields both oil and gas in paying quantities. In Section 1, west, a good showing of gas was obtained by the Carter Oil Co. in the Harrison Ford well. The "Clinton sand," 45 feet in thickness, was reached at a depth of 3,243 feet, and the pay, 5 feet in thickness, at 3,280 feet. The Kent Run Oil Co. obtained a small flow of gas in the test on the Peter Sale land in the central part of this section. The record, somewhat simplified, furnished by W. Hunter Atha, follows:

	Thickness in feet.	To top of formation.
Berea sandstone	10	817
Bedford and *Ohio* shales	1,343	827
"Big lime"	932	2,170
Shale	5	3,102
Shale, black	7	3,107
Shale	56	3,114
"Shell" lime	10	3,170
Shale	20	3,180
"Shells," sand, hard	10	3,200
Sand, red	16	3,210
Sand	28	3,226
Shale — *"Clinton"*	8	3,254
Sand	13	3,262

The total depth by rope measurement was 3,310 feet and by steel line 3,286 feet. Gas was liberated in the "Clinton sand" at a depth of 3,264 feet, and a showing of oil was found in the "Big lime" at 2,300 feet. Water occurred in the Waverly shales at a depth of 300 feet, and other flows in the "Big lime" at 2,835, 2,852, and 2,930 feet. In the fall of 1917 the Zane Co. was drilling on the farm of Howard Williams, located in the southern part of Section 1, west. In Section 12, west, the Carter Oil Co. failed to find the "Clinton sand" in the test on the farm of William Thompson. The drill struck the Berea sandstone, 28 feet in thickness, at 785 feet; the "Big lime," 955 in thickness, at 2,153 feet, and the horizon of the "Clinton sand" at 3,231 feet.

North of Fultonham, in Section 18, six wells have been drilled. The Zane Co. has one producing gas well on the E. S. Roberts property; one producing oil well, two abandoned oil wells, and one abandoned gas well on the W. J. Roberts farm. The record of the No. 2 well on the property of W. J. Roberts, furnished by W. Hunter Atha, is given below:

	Thickness in feet.	To top of formation.
Maxville limestone	42	98
Shale and sandstone	170	140
Big Injun sand (*Black Hand*)	260	310

	Thickness in feet.	To top of formation.
Shale and sandstone	323	570
Berea sandstone	14	893
Bedford and *Ohio* shales	1,347	907
"Big lime"	951	2,254
Shale	94	3,205
"Shells"	4	3,299
Shale	37	3,303
"Clinton sand"	38	3,340

Gas was struck in the "Clinton sand" at a depth of 3,350 feet, and oil at 3,352, 3,362, and 3,370 feet. The "Big lime" contained water at 2,956 and at 3,005 feet. This company also drilled a small gas well, now abandoned, on the farm of Harlin Thompson.

The largest gas well in the region, which had an initial flow of 2,500,000 cubic feet, but which is now abandoned, was drilled by the Carter Oil Co. on the property of Joseph Hough in Section 13, west. The Big Injun sand, 200 feet in thickness, was reached at 235 feet, the Berea sandstone, 20 feet in thickness, at 770 feet, the "Big lime," 955 feet in thickness, at 2,120 feet, and the "Clinton sand," 40 feet in thickness, at 3,208 feet. This company also obtained a gas well with 250,000 cubic feet initial production north of Jonathan Creek on the land of Lloyd Kroft.

In Section 19, two dry holes and four oil producers, three of which are now abandoned, have been drilled. The Zane Co. has one well still being pumped and one exhausted on the farm of J. F. Moore. A small well, which was soon abandoned, was also drilled by this company on the property of W. F. Lenhart. The record follows:

	Thickness in feet.	To top of formation.
Maxville limestone (*"Big lime"*)	65	35
Shale and sandstone	160	100
Big Injun sand (*Black Hand*)	260	260
Shale and sandstone	319	520
Berea sandstone	14	839
Bedford and *Ohio* shales	1,365	853
"Big lime"	948	2,218
Shale	109	3,166
"Shells"	21	3,275
Shale	20	3,296
"Clinton sand"	45	3,316

The "Big lime" contained water at depths of 2,927, 2,960, and 2,980 feet. This record shows the "Big lime" of the "Clinton sand" driller, which is the limestone formation of the Silurian and Devonian systems, and the "Big lime" of the Berea sandstone, which is the Maxville formation of the Mississippian system. The Big Injun sand in the above record is the Black Hand formation which is so well ex-

posed along its outcrop west of this in Perry County, and which is probably correlative with the Big Injun sand of the West Virginia and southeastern Ohio drillers.

The Peoples Gas Co. obtained only a showing of oil and gas in the test drilled on the L. S. Mauk farm; and Atha & Murphy secured one small oil well, now abandoned, and one dry hole on the J. W. Weller property. The drill in the Weller test struck the Maxville limestone, 35 feet in thickness, at a depth of 35 feet; the Big Injun sand, 245 feet in thickness, at 250 feet; the Berea sandstone, 17 feet in thickness, at 826 feet; the "Big lime", 961 feet in thickness, at 2,193 feet; and the "Clinton sand," 73 feet in thickness, and somewhat broken, at 3,289 feet. Neither oil nor gas in paying quantities was obtained by the Zane Co. in the test drilled on the land of Thurman Stoneburner in the central part of Section 25, nor on that of Thompson Brothers in the southern part of Section 8.

Madison Township.—The most eastern "Clinton" well in the northern part of Muskingum County is the test drilled by the Canadian-Ohio Oil Co. on the farm of A. B. Johnson, which is located north of Section 12, Madison Township, or about 2 miles south of Adams Mills. The drill started near the horizon of the Middle Kittanning coal and at an elevation of nearly 900 feet above tide. The record furnished by the Ohio Cities Gas Co. follows:

	Thickness in feet.	To top of formation.
Berea sandstone	30	1,015
Bedford and *Ohio* shales	1,495	1,045
"Big lime"	1,080	2,540
Shale and "shells"	121	3,620
"Clinton sand"	50	3,741
Total depth	-----	3,818

The sand was hard and only a showing of gas was secured. The great thickness of both the Bedford and Ohio shales and the "Big lime," with their increase towards the east, is of interest, and must be duly considered by those desiring to reach the "Clinton sand" under still greater covering.

Washington Township.—In Washington Township only one test of the "Clinton sand" has been made. The well drilled by the Ohio-Rochester Co. on the farm of Robert Lucas is located along the small stream just north of where the Baltimore & Ohio Railroad leaves the Muskingum Valley. The log furnished by the Ohio Cities Gas Co. is given below:

	Thickness in feet.	To top of formation.
Sand and gravel	54	-----
Shale and sandstone	306	54
Big Injun sand	40	360
Shale and sandstone	485	400
Berea sandstone	20	885

	Thickness in feet.	To top of formation.
Bedford and *Ohio* shales	1,500	905
"Big lime"	1,071	2,405
Shale and "shells"	176	3,476
"Clinton sand"	41	3,646
Total depth	-----	3,707

The sand was dry and hard. In the "Big lime" a break was present from 3,455 to 3,466 feet, and water was found at depths of 2,605 and 3,195 feet. The wellhead is near the horizon of the Upper Mercer limestone.

Perry Township.—The most eastern "Clinton" well in Muskingum County is located in the southwestern corner of Perry Township on the property of George Handschy, and was drilled by the Zanesville Gas & Oil Co. in 1909. The record of the test furnished by the Ohio Cities Gas Co. follows:

	Thickness in feet.	To top of formation.
Berea sandstone	23	1,010
Bedford and *Ohio* shales	1,607	1,033
"Big lime"	1,005	2,640
Shale	60	3,645
"Clinton sand"	38	3,705
Total depth	-----	3,805

The sand had good texture, but it contained neither oil nor gas. In the Berea sandstone, however, a showing of oil was secured. Water was present in the "Big lime" at depths of 3,486 and 3,544 feet, and the casing (5 inch) was set at 3,553 feet.

Adjacent Territory.—Up to the fall of 1917 no "Clinton" tests had been made in the southern part of the county, except those in Newton Township. Small oil fields, however, are present near Cooksville and near Saltillo in Perry County, and drilling has been done farther south in Morgan County. In order to show the position of the sand there is given below a record of the James A. Watts well No. 1, located in Section 17, Harrison Township, Perry County, and owned by Lewis Emery Jr. & Sons:

	Thickness in feet.	To top of formation.
Berea sandstone	23	1,025
Bedford and *Ohio* shales	1,407	1,048
"Big lime"	945	2,455
Shale and "shells"	160	3,400
"Clinton sand"	32	3,560

In September, 1894, a deep well was begun at McConnelsville, the town council having provided $5,000 to meet the expense. Progress was slow. By the middle of the next March a depth of 3,186 feet was reached, and the tools, having become fast, the well was abandoned. Following is a record of this well:[1]

[1]Geol. Survey Ohio, 4th Ser., Bull. 12, pp. 37-8.

	Thickness in feet.	To top of formation.
Surface material	15	-----
Shale, sandstone, clay, and coal	610	15
Maxville limestone or *"Big lime"*	44	625
Keener sand	40	669
Shale and sandstone	86	709
Big Injun sand	45	795
Cuyahoga shales	409	840
Sunbury (*Berea*) shales	30	1,249
Berea sandstone	66	1,279
Bedford sandstone and shales	25	1,345
Ohio shales	1,712	1,370
"Big lime"	-----	3,082
Total depth	-----	3,186

As the record shows, the drill stopped far short of the "Clinton," and while it was a failure as far as its object was concerned, it performed a useful service to geology by providing additional information on the deeper formation in this part of Ohio. The point of most interest is the great thickness of the Ohio shales.

BEREA SANDSTONE

The Berea sandstone, or sand of the oil driller, which was named from exposures near Berea, Cuyahoga County, is widely distributed in Ohio. Its outcrop extends westward from Ashtabula County across Lake, Cuyahoga, and Lorain to Erie, thence southward across Huron, Crawford, Morrow, Delaware, Franklin, Pickaway, Ross, and Pike to Adams County on the Ohio River. Under cover the bed has been traced by the drill almost continuously eastward to Pennsylvania and southward to West Virginia and Kentucky. Orton states: "the entire area occupied by the formation in Ohio is not less than 20,000 square miles."[1]

The Berea is a rather firmly cemented, medium-grained sandstone of a light or bluish-gray color. The sandstone layers, varying from a few inches to several feet in thickness, are separated by shale partings, ranging usually through somewhat smaller limits. In places the sandstones are separated only by a bedding plane, or by a very thin layer of argillaceous matter. The sandstones are usually uniformly bedded, but in some deposits one or more layers may have a concretionary structure. More shaly material is found in the lower part of the formation. The sandstone is highly ripple-marked, and not infrequently is imprinted by worm tracks.

In eastern Ohio for many years the Berea has been one of the important sands for both oil and gas, and its production is yet large. Moreover, new pools are being found from time to time as prospecting

[1]Geol. Survey Ohio, Vol. VI, p. 324.

continues. The oil is usually of low gravity and has a high rating. Concerning its accumulation Orton says:[1]

The source of the oil in the Berea grit is not doubtful or problematic, it is obvious and demonstrable. The oil is derived from the great shale series which underlies the sandstone and is simply stored in the sandstone as a reservoir. The shales are an adequate source and they are directly at hand. They contain free petroleum through their whole extent. Some storage is effected in the shales themselves. The hard bands are often found, as the drill descends through them, to hold small accumulations of either oil or gas, but the great accumulations pertaining to them are in all cases effected by sandstones or conglomerates that are buried in the shales. The Berea grit, being the only regular sandstone contained in the Ohio shales within the limits of the State, becomes, as has been noted, a universal source of these bituminous products.

The conditions for these accumulations, as far as source is concerned, are absolutely universal throughout the territory occupied by the Berea grit. There is everywhere underlying the Berea grit an abundant source of oil and gas. A second condition which, like the first, is indispensable to oil accumulation, viz., an impervious cover to the oil rock, is found wherever the Berea grit has its normal roof, viz., the Berea and Cuyahoga shales, but it has this normal roof wherever it lies deep enough to retain it. This condition is also complied with to a large extent throughout the territory in question. A third requisite for oil and gas accumulation, the Berea grit itself meets. As has been already shown, it constitutes a reservoir for both substances. It cannot, however, be claimed that it meets this requisite as effectively and as constantly as the two series of shales that serve respectively as source and as cover meet the conditions imposed on them. It is doubtless too fine-grained and too close in parts of its extent to make good oil rock. Its thickness is also, in many instances, too small to afford large storage. But still it is true that so far as can be seen, this condition of a reservoir is also fulfilled on a very large scale in the territory under consideration and we can, accordingly, declare that the three principal requisites and conditions ordinarily laid down for petroleum accumulation occur throughout a large portion of eastern Ohio.

But, although these conditions are present, the stocks of oil that become valuable to us have not been gathered, except at a very few points. It is obvious, therefore that there is some other essential requisite for large production. This requisite we find in peculiarities of geological structure. There is a small accumulation in the Berea grit almost everywhere, by virtue of its relation to the shales, that respectively support it and make its roof, but the oil and gas fields that deserve the name seem to be characterized in all instances by departure from the regularity of structure which belongs to eastern Ohio generally.

In Muskingum County two pools of oil are present in the Berea sandstone and both show structural features. In the Otsego pool the oil is found along the west slope of an anticline, the crest of which, measured by the Middle Kittanning coal, is nearly 100 feet above the trough. In the higher parts some gas is found, and in the lower parts water is always encountered. In the Cannelville field the structure is more irregular, as it consists of a number of small anticlines and domes, which are distinctly isolated or poorly connected. These features will be treated in more detail when the fields are considered in their proper order. In this county the position of the Berea sandstone,

[1]Geol. Survey Ohio, Vol. VI, pp. 325-6.

on the average, is nearly 2,446 feet above the "Clinton sand," 1,338 feet above the "Big lime," 735 feet below the Maxville limestone, and 990 feet below the Middle Kittanning coal. The rock is very persistent over the entire area, but in places it is broken or hard. Drill records show that the bed averages 21 feet in thickness, but that it varies from a minimum of 8 feet to a maximum of 50. The wells, which had for their direct object the exploitation of the Berea sandstone will be given by townships.

Jackson Township.—Aside from the many "Clinton" wells, which of course passed through the Berea, only one test of this sandstone has been made in Jackson Township. The well was drilled by L. W. Doane near the bank of Wakatomika Creek on the farm of William Norman, which is located about 2 miles northwest of Frazeysburg. The depth was 764 feet and the results unfavorable.

Cass Township.—The search for oil or gas in the Berea sandstone in Cass Township has been confined to three tests which were unpromising. A local company from Dresden drilled a well with only a showing of oil on the farm of S. Cowden, which is located one-half mile northwest of the village, and another with much the same results on the property of Joseph McFarland, which is located just east of the Elberson School. Another attempt on the L. H. Stafford farm, about 2 miles south of Dresden, was also without success. The sand at this place was reached at a depth of 936 feet.

Jefferson Township.—A test yielding only a flow of salt brine was drilled in the northern part of Dresden by a local company. The depth reported is about 900 feet.

Licking and Muskingum Townships.—The drilling in both Licking and Muskingum townships has all been deep, that is, to the "Clinton sand." In the many holes so far put down the Berea sandstone is regularly present, but it has given not more than a showing of either oil or gas. Salt water is usually encountered in this formation.

Hopewell Township.—In Hopewell Township the drilling, with one exception, has extended below the Berea to the "Clinton sand." In 1909 Tate drilled a well on the William Burley farm, in Section 22, to a depth of 1,060 feet. Only a showing of oil and gas was secured.

Falls Township.—In Falls Township but little work has been done in testing either the Berea or "Clinton" sands. However, the results so far have not been encouraging. An attempt was made at the plant of the American Encaustic Tiling Co. to reach the "Clinton sand," but the drill stopped in the "Big lime." The Berea sandstone was found at a depth of 850 feet, but it was unproductive.

Springfield Township.—As far as could be ascertained by the writer, four wells in Springfield Township were drilled to the Berea sandstone. One of these was located near the west bank of the Muskingum River just south of the Y bridge at Zanesville. Probably the

earliest attempt at production was the test drilled in 1884 by the Zanesville Heating Co. just south of Washington Street in Putnam. The record of the well somewhat revised is given below.[1]

	Thickness in feet.	To top of formation.
Bedrock	14	-----
Limestone [*Lower Mercer*]	3	14
Shale and sandstone	35	17
Coal and sandstone	15	52
Shale and sandstone	21	67
Coal and shale	6	88
Shale	36	94
White sandstone [*Sharon*]	5	130
Shale	15	135
Light shale	200	150
Gray sandstone with salt water [*Black Hand*]	70	350
Shales	30	420
Light shale	210	450
White sandstone	5	660
Dark and light shales	175	665
White sandstone with oil and water [*Berea*]	20	840
Red sandstone, Dark and light shale [*Bedford* and *Ohio*]	10 1,149	860 870

The terms in brackets were supplied by the writer.

A good showing of oil was secured. At the plant of the National Paving Brick Co., South Zanesville, Culp Bros. drilled a well 1,600 feet deep, but secured only a showing of gas. They also made a test of the Berea sandstone in Section 15, but secured no production.

Newton Township.—A number of tests have been drilled in Newton Township, but aside from a few wells in the southeastern part of the area the results have been discouraging. The White Cottage Oil & Gas Co. failed to secure production in the well on the Seymour Johnson property in the northern part of Section 8, or in that on the Dwight Weeks land in the southwestern part of Section 9. In the latter a showing of oil was obtained. W. Hunter Atha drilled a dry hole on the property of the Southeastern Railway Co. just east of the village of Elizabeth in Section 10. The Berea sandstone was unproductive where tested by Caffrey, Hyatt & Co. on the Jesse M. Baughman property in the southeastern part of Section 24. Similar results were obtained by E. T. Caffrey on the land of David F. Carr in the northeastern part of Section 26. A showing of oil was found in the Berea sandstone by the Caffrey-Davis Oil Co. on the Lincoln Baughman property, and by Caffrey, Hyatt & Co. on the John Spring farm, both in the southern part of Section 26. The Clay Oil & Gas Co. obtained a small oil producer, now abandoned, on the land of John Towning, in the south-

[1]Geol. Survey Ohio, Vol. VI, p. 373.

eastern part of Section 36, and Charles Bell and others a gas producer and a dry hole on that of Ira Zeigler in the south central part of the same section. The record of the Zeigler well follows:

	Thickness in feet.	To top of formation.
Middle Kittanning coal	2	53
Maxville limestone	43	280
Black Hand conglomerate or *Big Injun* sand	30	520
Berea sandstone	19	1,033

In the southwestern part of Section 36, on the Amanda Helriggle property, a gas producer was drilled by E. F. Caffrey and a dry hole by Proudfit & Carson.

Clay Township—Small pools, outliers of the main Cannelville field, are present in northeastern Clay Township. The production includes both oil and gas. The general structure appears to be that of a small dome with gas in the upper part and with oil down the slope to the southeast. An extension of the Cannelville pool also enters the northeastern part of Section 1. For the most part the wells were drilled in the years 1915 and 1916, but the search for new production is not yet ended (1918).

In Section 1 the Clay Oil & Gas Co. has one oil well on the property of John Towning, and five oil wells and two dry holes on that of A. S. Cherry. On the Cherry farm a test was also made much earlier than this, but it gave only a showing of gas. South of this, on the C. S. Swingle farm, the Wasmuth & Callahan Oil Co. has five oil wells, two dry holes, and three locations. In the southwestern part of the section, on the land of Charles Ballou, the results in the fall of 1917 were nine producing and three abandoned oil wells and one location. A flow of gas was obtained by the Southeastern Oil & Gas Co. on the farm of M. Swackhamer, which is located in the western part of the area.

Gas is the principal product obtained from the Berea sandstone in Section 2, but some oil is also secured. On the land owned by Edward Ransbottom, in the southeastern part of the area, the Wasmuth & Callahan Oil Co. has eight gas wells and one oil well. West of this, on the farm of Albert Thorp, the drill operated by Howard Buker struck oil in three tests, and gas in one, now abandoned. In the northeastern part of Section 11 the Ohio Fuel Supply Co. drilled two oil producers on land of William Shinger, and one dry hole on that of C. H. Rambo.

The main oil production is in the northern part of Section 12 where drilling is still going on. In the fall of 1917 the Ohio Fuel Supply Co. had eight oil producers on the farm of William Rhodes, one on that of Charles Ballou, and one test with a showing of gas on the C. M. Diltz property. East of this, on the B. F. Thompson farm, the Leonard

Petroleum Co. controls seven oil wells and one dry hole, and the Ohio Fuel Supply Co. three oil wells. The Berea sandstone where tested on the farm of Robert Hand gave no reward for the labor and money invested by the Oil City Producing Co. The depth of most of these wells is between 1,000 and 1,200 feet, and the thickness of the Berea sandstone between 15 and 30 feet. The interval from the top of the sand to the top of the Maxville limestone is about 750 feet and that to the Middle Kittanning coal is nearly 970 feet. No tests were found in 1917 in the southern part of Clay Township.

Brush Creek Township.—The most important oil field in the southern part of Muskingum County is in the vicinity of Cannelville in Brush Creek Township. A few small gas wells are also present. When visited in the fall of 1917, the field contained 75 producing and five abandoned oil wells, four gas wells, and 26 dry holes. Since then other tests have been made, but the results are not known. Most of the drilling was done in the years 1915-1916. The general trend of the main part of the field is in a north-south direction, from the central part of Section 27, through sections 5 and 8, to the northern part of Section 17. An outlying pool is also present in the southern part of Section 26 and the northern part of Section 6. The structure is broken and irregular and consists more of isolated domes than of a well-defined anticline. The initial production of the wells was small, usually between 10 and 40 barrels, but the settled production holds up very satisfactorily.

In Section 26 the Clay Oil & Gas Co. has two oil wells on the farm of W. H. Jenkins and one dry hole on that of Robert McConnell. Perry & Drury failed to find either oil or gas in paying quantities in the test put down on the tract of John Elson. In Section 6 the Clay Oil & Gas Co. owns 17 producing and two abandoned oil wells on the land of C. L. Gallogly, four oil wells and one dry hole on that of A. B. Showers, and one producer on the Sloan property. Only dry holes were obtained in the two tests drilled by the Denman Oil Co. and by the Bluerock Oil & Gas Co. on the farm of O. L. Wilson. The record of the Wilson No. 2 well follows:

	Thickness in feet.	To top of formation.
Upper Freeport coal	4	26
Middle Kittanning coal	2	121
Maxville limestone	65	340
Black Hand or *Big Injun* sand	32	605
Berea sandstone	17	1,098

The Big Injun sand nearly always gives a flow of water that requires casing. In the Berea the pay is near the base of the formation.

A part of the main Cannelville field is found along the Brush Creek Valley in the southern part of Section 27. In this area the Bluerock Oil & Gas Co. owns 16 producing and one abandoned oil wells on the

farm of Lewis H. Swingle, and two producers on that of John M. Morgan. The Southern Oil & Gas Co., however, failed to find production in the Berea sandstone on the land of Jacob Deiterick. In most of these wells the sand is 20 to 30 feet in thickness and of good texture. The average interval from the top of the Berea sandstone to the top of the Big Injun, 25 feet in thickness, is 480 feet; to that of the Maxville limestone, 53 feet in thickness, is 738 feet; and to that of the Middle Kittanning coal, 3 feet in thickness, is 985 feet.

The oil pool extends in a north-south direction across the central part of Section 5 where drilling is yet going on. In the fall of 1917 the Bluerock Oil & Gas Co. had four producers and one dry hole on land of Alva Jenkins, and two pumpers and three unproductive wells on that of Lucinda Moody. The Neely-Clover Co. failed to get results in the test drilled on the farm of Lucinda Moody, but secured three producers on that of Clarence Harrop, three on that of William Boyd, three on that of Margaret Boyd, three on the property of G. R. Ballou and one on the farm of Clarence Anderson. Howard Swingle obtained only a showing of oil and gas in a well on the William Boyd property. The Bluerock Oil & Gas Co. controls two producers on the tract of Robert Bigrigg, and the Leonard Petroleum Co. seven producers and one dry hole on that of Thomas Harrop. A record of the Moody No. 4 well follows:

	Thickness in feet.	To top of formation.
Middle Kittanning coal	3½	95
Black Hand or *Big Injun* sand	40	590
Berea sandstone	19	1,079

Both oil and gas have been secured in Section 8. The Brush Creek Oil & Gas Co. has seven oil producers on the farm of William Longstreth, and the Leonard Petroleum Co. two on that of C. E. Dozer. On the land of Francis Swingle the results obtained by the Greenlee Oil & Gas Co. were one producer and one abandoned oil well, two gas wells, and four unproductive tests. Each of the gas wells is reported to be producing about 50,000 cubic feet per day. An old well on the Dan and Charles Morningstar farm gave only a showing of gas, but a well drilled in 1916 by W. F. Forsyth & Co. gave a good flow, which is used locally for domestic purposes. The main body of the gas, however, is from a Pottsville sand and not from the Berea. The record furnished by Mr. Forsyth follows:

	Thickness in feet.	To top of formation.
Middle Kittanning coal	1	180
Sand with gas	-----	390
Berea sandstone	17	1,142

The Berea sandstone gave only a small showing of oil and gas. In the western part of Section 9, Swingle & Fritz drilled two dry holes

on the farm of Jacob Helriggle, and D. D. Flannigan two on that of James Tweed. In the northeastern part of Section 17 the Greenlee Oil & Gas Co. obtained a small gas well and a dry hole on the Emmit Swingle farm, and the Swingle Oil Co. a showing of gas on the T. B. Weaver property. Near the head of Duncan Run, in the southern part of Section 23, a good flow of gas was obtained in the Berea sandstone in the test drilled on the land of S. M. Swingle. Along the stream in the central part of Section 15, Caffrey, Hyatt & Co. failed to secure results in the well drilled on the farm of Jesse Longshore, or in the one on that of James J. French.

Harrison Township.—A number of tests of the Berea sandstone have been made in Harrison Township, but so far it has given neither oil nor gas in paying quantities. Just south of Philo, on the Charles H. Howell farm, an attempt was made to reach the Berea sandstone, but owing to various troubles the drill stopped just below the Black Hand or Big Injun sand in which some gas as well as salt water was encountered. In this test 40 feet of Maxville limestone was found at a depth of 320 feet and 80 feet of Big Injun sand at 520 feet. The Berea sandstone gave only a showing of oil and gas where tested on the land of August Kullman in the southwestern part of Section 5. In this test 30 feet of Maxville limestone was found at a depth of 310 feet, 55 feet of Big Injun sand at 520 feet, and 16 feet of Berea sandstone at 1,028 feet. The total depth of the well was 1,245 feet. A dry hole was also drilled on the R. Prescott farm in the northeastern part of Section 21. The record furnished by Charles H. Howell follows:

	Thickness in feet.	To top of formation.
Gravel	20	-----
Sandstone	40	20
Shale	140	60
Sandstone	25	200
Shale	85	225
Maxville limestone	40	310
Shale	225	350
Big Injun sand	25	575
Shales	400	600
Berea	50	1,000

A showing of oil was obtained by E. N. Taylor in the well drilled on the T. Olden farm in the southern part of Section 11 where the drill descended to a depth of 1,850 feet, or far below the Berea sandstone. Another attempt on the same property, but in the northern part of Section 14, was also without success. The depth reported is 1,122 feet. C. A. Leeper drilled two Berea wells on the William White property in Section 31. No production was obtained. At Cedar Run, in Section 32, on land of Frank Price, only a showing of oil was found in the Berea.

Bluerock Township.—The work so far in Bluerock Township has

failed to reveal either oil or gas in paying quantities in the Berea sandstone. Small pools, however, are present in the Cow Run sand not far east of its outcrop. The most northern Berea well in the area when the region was visited was that on the farm of Mrs. J. M. Ward, which is located in the northeastern part of Section 4. The well is near the bank of Manns Fork of Salt Creek and gave a showing of oil and gas. The depth reported is about 1,200 feet. The Berea sandstone was dry where tested on the farm of L. G. Buchanan, in the southeastern part of Section 11. Similar results were obtained in a well, the depth of which is reported to be 2,750 feet, drilled in the southwestern corner of Section 14 on the land of B. S. Peyton. This well is within the boundaries of the abandoned Cow Run pool which produced oil for many years. In the J. E. Shover well, located in the northern part of Section 13, and drilled by local parties, only a showing of gas was secured. A test made by the same people on the land of A. F. Cohagan was also unsuccessful. A showing of gas was obtained in a well reported to have reached the Berea, and which was drilled by Arndoff Bros. on the I. O. Barr farm in the northern part of Section 28. The location chosen for the work is near the bank of Dry Riffle Run. In 1902 a Berea well with a little oil was drilled in the southeastern part of Section 33 on the farm of Andrew Finley. Along the Muskingum River near Irish Rock in Section 32, Carr Brothers & Jewett, in 1886, made a test of the Berea sandstone on the W. S. Bell property. The record somewhat revised is given below:[1]

	Thickness in feet.	To top of formation.
Surface	14	-----
Sandstone	5	14
Shale and clay	56	19
Sandstone	14	75
Clay and shale	109	89
Sandstone	5	198
Clay and shale	43	203
White sandstone with gas [*Mercer* horizon]	8	246
Shale and clay	114	254
Red clay	16	368
Limestone [*Maxville*]	10	384
Shales	194	394
Conglomerate with break at 60 feet [*Black Hand* or *Big Injun*]	180	588
Shales	255	768
Sandstone, hard [*Cuyahoga*]	9	1,023
Black shale [*Sunbury*]	41	1,032
Berea sand	15	1,073
Red shale [*Bedford*]	10	1,088

The wellhead is only a few feet above the horizon of the Upper Freeport coal. A small yield of oil with some gas was obtained. The

[1]Geol. Survey Ohio, Vol. VI, p. 375.

well was soon abandoned. The results so far in Bluerock Township have been discouraging, but as the tests are widely scattered small pools may yet be struck by the drill.

Meigs Township.—From the information obtained in the field the Berea sandstone has been exploited at only two places in Meigs Township. One of these was on the J. T. White farm in the central part of Section 6, and the location chosen was on the south bank of Kent Run. The test is reported dry and about 1,400 feet in depth. The other well is on the W. R. Simms property in the southwestern part of Section 13. A showing of oil was obtained at a depth of approximately 1,700 feet.

Rich Hill Township.—In Rich Hill Township 12 tests that had reached the Berea sandstone were found. Some of these gave a good showing of oil, but few were shot and none pumped. The Berea sandstone was unproductive where tested on the farm of Andrew Craig in Section 7. The Ohio Fuel Supply Co. secured a good showing of oil on the Jennie Miller property in the northeastern corner of Section 10. The depth reported is about 1,200 feet. East of this, in the northwestern part of Section 11, on the Samuel Herdman land, Joseph McLaughlin obtained similar results. On the land of M. K. Bolin, in the northern part of Section 13, the Berea sandstone was dry where tested by Joseph McLaughlin. South of this, two holes with showings of gas have been drilled on the property of John Huhn. William Longfellow obtained a good showing of oil in one test on the land of Charles Elliott in the central part of Section 16, two wells on the farm of Elba Howell in the eastern part of Section 20, and in one test on the property of G. M. Thorla in the central part of the same section. Also in Section 20, Frank Wordly obtained similar results on the farm of George Miller. The most southern Berea well in the township is on the W. N. Miller farm in the central part of Section 29, but the sand found at a depth of about 1,400 feet gave only a showing of oil.

Salt Creek Township.—In Salt Creek Township, although good showings of both oil and gas have been secured, no production had been obtained to the time the region was visited in 1917, though the Berea sandstone had been reached by the drill in 10 well-distributed tests in the area. The most northern well, considered a dry hole, where the sandstone was found at a depth of 993 feet, is on the W. J. Wilson farm in Section 4. The location chosen is near the east bank of Salt Creek. In the eastern part of Section 11, the drill operated by Corry & Veezy liberated a good showing of gas at a depth of about 1,200 feet on the farm of W. J. McConaha. Bachelor Bros. drilled two wells in the northeastern corner of Section 20. The one on the A. W. Barnes property gave a showing of gas, but that on the C. E. Wilhelm farm produced only brine. In the northern part of Section 23 Frank Wordly obtained a showing of oil and gas on the farm of Robert Clapper, and

a showing of oil on that of A. H. Cline. The Cline well is reported about 1,500 feet in depth, and the Clapper well considerably deeper. Culp Bros. obtained a good flow of gas in the Berea sandstone at a depth of about 1,200 feet in the well drilled on the property of Sadie Williams in the southern part of Section 27. About one-fourth mile south of the Elliot School, in the eastern part of Section 28, only a showing of gas was found by Culp Bros. on the C. W. Murphy farm. Carr Bros. secured only showings of gas in two tests put down on the farm of Charles F. Cline, which is located in the southeastern part of Section 33. The showings of oil and gas in this township indicate that small pools may yet be located.

Wayne Township.—One of the early attempts for oil or gas in Muskingum County was made in Wayne Township, but so far the results of drilling have been discouraging. About 1885 a well was drilled by the Zanesville Heating Co. on the farm of L. V. Bishop in Section 4. The Berea sandstone was struck at a depth of 847 feet, but it gave only a showing of oil and gas. On the property of M. F. Fisher the Wayne Oil & Gas Co. sunk a well far below the Berea sandstone, but obtained neither oil nor gas in commercial quantity. The depth reported is about 2,500 feet. This company secured only a showing of oil and gas in the Berea sandstone, which was reached at a depth of 1,010 feet on the Joseph Ellerman farm in the southeastern part of Section 14. Along the Muskingum River, about 1 mile west of Duncan Falls, the sand was again penetrated, but failed to yield rewards. The work was done by a local company from Zanesville and the depth reached is reported to be about 1,100 feet.

Washington Township.—The Berea sandstone in Washington Township has failed to reward the operators with good production of either oil or gas. Several tests, however, have shown small quantities of one or the other. Years ago a well was drilled north of Zanesville near the mouth of Mill Run. No definite information regarding the depth or results was obtained. On the farm of Theodore Fox, about 3 miles northeast of Zanesville, four wells were drilled to the Berea sandstone, which was found at a depth of about 1,100 feet. Of these, one well, now abandoned, yielded a small quantity of oil, but the other three gave only a good showing. St. Clair Elliot drilled an unproductive test on the H. A. Mangold farm in the northern part of Section 11. The Taylor Oil Co. in 1917-18 drilled three tests 2 miles northeast of Gilbert, and these gave showings of oil. The log of the No. 1 well on the Arthur Stotts farm is given below:

	Thickness in feet.	To top of formation.
Soil	20	-----
Blue shale	50	20
Gray limestone, *Putnam Hill*	5	70
Light shale	20	75

		Thickness in feet.	To top of formation.
Gray sandstone, broken		25	95
Black shale		15	120
Black limestone, *Upper Mercer*		6	135
Dark shale		18	141
Dark limestone, *Lower Mercer*		5	159
Blue shale		40	164
Light shale		40	204
Dark shale		60	244
Sandstone, pebbly, broken, *Sharon conglomerate*		25	304
Light shale		51	329
Dark shale		50	380
Sandstone, *Black Hand* or *Big Injun*		50	430
Light and dark shale	*Cuyahoga*	210	480
Sandstone and shales		20	690
Light shale		60	710
Blue shale		30	770
Light shale		120	800
Brown shale, *Sunbury*		44	920
Sandstone, *Berea*		26	964
Red shale, *Bedford*		11	990

The wellhead has an elevation of 817 feet above tide and is 5 feet below the top of the Middle Kittanning coal. A small quantity of light oil with considerable brine was obtained. The results were similar in the No. 2 well drilled on the same farm. A small flow of gas and water was struck, however, at a depth of only 60 feet. In this well 18 feet of Berea sandstone was found at a depth of 965 feet. The elevation of the wellhead is 799 feet above tide. The third well put down by this company was on the property of W. H. Woodrow, and yielded only a very light showing of black oil with salt brines. A partial record is given below.

	Thickness in feet.	To top of formation
Black limestone, *Upper Mercer*	7	210
Dark limestone, *Lower Mercer*	5	230
Gray limestone, *Maxville*	5	420
Gray sandstone, *Black Hand* or *Big Injun*	60	530
Brown shale, *Sunbury*	35	1,030
Sandstone, *Berea*	25	1,065

On the J. J. Bowers property, near the White School, the Berea sandstone tested by Joseph McLaughlin gave only a showing of oil. The well is reported to be 934 feet in depth and to be 10 feet below the base of the Berea sandstone. The elevation of the wellhead is 767 feet above tide.

Perry Township.—Perry Township has not been an attractive field for the driller as only two wells to the Berea sandstone were found when the region was visited in 1917. The drill operated by William Longfellow reached the Berea at a depth of 1,380 feet on the A. M. Burwell farm in the northern part of Section 13. It gave a showing of gas.

In 1908, W. Hunter Atha made a test on the farm of Dan Smithey, which is located near the Pleasant Valley School in the southwest part of Section 21. The top of the Berea was reached at a depth of 1,128 feet, but the formation contained only a small quantity of oil with some gas.

Union Township.—There were two tests of the Berea sandstone found in Union Township. One is on the farm of Richard Rice, which is located about 2½ miles south of New Concord. In this the drill struck the top of the Berea sandstone at a depth of 1,286 feet, the bottom at 1,328 feet, and finished at 1,335 feet. The only reward was salt water. A bed of cannel coal, however, was reported at a depth of 350 feet. The other well was drilled by Joseph McLaughlin on the Thomas Stewart farm in the northeastern part of Section 24, but it was unproductive.

Madison Township.—The drilling to the Berea sandstone as well as that to the "Clinton" has failed to show any pools of either oil or gas in Madison Township. About 20 years ago a local company from Dresden drilled a well about 1,000 feet in depth and with a good showing of oil on the farm of Grant Little, which is located nearly 2 miles east of Dresden. About 10 years ago another attempt to secure production, but which failed, was also made on the same property. This test was only 980 feet in depth. Other wells which were failures were drilled on the farm of Miles Lane in the northeastern part of Section 18, and on that of John Dickey in the southeastern part of Section 23.

Salem Township.—Only three Berea wells were found in Salem Township. In 1899 a local company made a test on the farm of R. B. Shirer, which is located about 2 miles east of Adamsville, but it secured only a showing of oil and gas. The Berea sandstone, 20 feet in thickness, was struck at a depth of 1,176 feet. This company also made another attempt to secure production on the C. A. Geyer property, just east of Adamsville. In this well the Middle Kittanning coal, 3 feet in thickness, was found at a depth of 150 feet, and the Berea sandstone, 28 feet in thickness, at 1,200 feet. A small quantity of a heavy black oil was present in the top of the sand, but a strong flow of salt water was liberated at lower levels. Results much like those in the above tests were obtained in the well drilled on the John Bowden farm in the east central part of the township.

Adams Township.—The search for fuel in the Berea sandstone in Adams Township has been confined to only one test, which was drilled just east of Young America School in Section 19. The well is located on the farm of George W. Slater, but it yielded little except salt brine. In the adjacent area, or near the Robison Bridge on Wills Creek, in Franklin Township, Coshocton County, a Berea well with a showing of oil and a strong flow of salt brine was put down by the W. C. Kennedy Co. on the farm of Mary B. Robison.

Highland Township.—The anticline upon which the main Otsego oil pool of Monroe Township is located extends southward into the

northeastern part of Highland Township. Along this a small pool in the northeastern part of the area was opened about 10 years ago. The initial production of the wells was 5 to 30 barrels, and the present yield about one-half barrel per day. The Berea sandstone in this area is 980 to 1,000 feet below the Middle Kittanning coal, which is the best bench for reference. Some drilling is yet in progress in the area. In Section 1, the White Eyes Oil & Gas Co. has four producing oil wells and one dry hole on the farm of G. D. Mossholder. C. P. Price has three producers on the J. G. Griffin property, and the Bloomfield Oil & Gas Co. one abandoned well on the F. Russel land. In the eastern part of Section 2 the White Eyes Oil & Gas Co. failed to secure production on the Edward Morrow farm. Only showings of oil with brine were obtained by the Bloomfield Oil & Gas Co. on the W. B. Strickler farm in the northeastern part of Section 3; by the Bell Oil Co. on the James Morgan land in the southwestern part of Section 9; and by the Cameron Oil Co. on the J. G. McCormick property in the central part of Section 7. Future drilling will probably enlarge the present pool and may locate other small ones.

Monroe Township.—The largest field of oil in the Berea sandstone of Muskingum County is that known as the Otsego in Monroe Township. Local parties discovered oil in this locality about 15 years ago, and they have been largely instrumental in its further development. In the fall of 1917 the count stood 157 producing and 10 abandoned oil wells, 3 gas wells, and 32 dry holes. The daily production was nearly 75 barrels of oil and 500,000 cubic feet of gas. The initial production of the largest wells was only from 20 to 40 barrels, and that of the average well from 2 to 10 barrels. Although the production was never large, it has held up well. The field has passed its maximum yield, but it bids fair to be a source of considerable revenue for at least a number of years.

The Berea sandstone in this region is 20 to 30 feet in thickness and very persistent. The oil is found mainly in the lower half. Further, the sand generally yields considerable brine. The interval from the Middle Kittanning coal, which is the main bench for reference, to the top of the Berea sandstone is about 985 feet, and that to the pay nearly 1,000 feet. This field conforms well to rock structure, the general trend of which is a few degrees west of north. In this township the anticline based on the rise of the Middle Kittanning coal is about 100 feet in height. From well records the structure in the Berea sandstone conforms closely to that indicated by the coal. Along this structure brine is found in the syncline to the west, oil on the west slope of the anticline, some gas in the top, and a little oil on the east slope. This fold was traced from Linton Township, Coshocton County, through Monroe Township, Muskingum County, to northern Highland Township. It flattens or becomes broken in the northern part of Union Township.

The trend of the main oil production is from the small Wertz pool in sections 6 and 15, Linton Township, Coshocton County, through the Otsego pool in sections 3, 8, 12, 13, and 21, Monroe Township, Muskingum County, to that in Section 1, Highland Township. The belt along which gas is present in most places extends from the small field about 1 mile west of West Lafayette, Coshocton County, to the southeastern part of Knox Township, Guernsey County. The wells in the Otsego pool make enough gas to do the pumping. Each power operates 3 to 10 wells by means of shackle lines. Most of the wells yield not only oil, but salt water, which is separated from the oil in the tanks by drainage. The field is supplied with a pipe line and pumping station which easily takes care of the production. Drilling was not active in this area in 1917.

The Bell Oil Co. obtained only a showing of gas in the Berea sandstone on the Grover Sprague farm, located in the northwestern part of Section 1. A test reported dry was drilled on the property of Nancy McAllister in the western part of Section 2. A part of the main Otsego pool is found in Section 3, in which area 34 wells have been drilled. The Denman Oil Co. has three oil producers on the land of Ora Snoots, a dry hole and a producer on that of the Ross heirs, two producers on that of Burt Erman, one on that of J. E. Simmons, and seven on that of Thomas Bell. The Lane Oil & Gas Co. controls five producers on the John Trimble farm, five producers on the H. C. Magnass land, and five producers on the Peter Holsky property. The Seville Oil & Gas Co. drilled a dry hole on the tract of John Trimble, and the Spring Run Oil Co. a small well, now abandoned, on that of Susie Osborne. On the Osborne property, however, Bell Bros. have two producing wells.

The only wells drilled in Section 4 are along the eastern boundary and are all producing oil in paying quantities. On the Jane Cowden farm are four wells controlled by the Lane Oil & Gas Co., and on the Susie Osborne property 1 owned by Bell Bros. No tests have been made in sections 5 and 6, and only one which gave a showing of oil in Section 7. The well was drilled by John Conner on the T. J. Sprague farm, located in the southeastern corner of the area.

A large number of oil producers as well as a few dry holes are present in Section 8. The Lane Oil & Gas Co. controls one producing and one abandoned oil well on the land of L. S. Case, one producer on that of the Hamilton heirs, and two producers on that of Peter Holsky. A small well, soon abandoned, was drilled on the Frank Bradford property, and another on the Frank Wortman farm. The Giles-Harbison Co. owns one producer on land of the Hamilton heirs, one on that of Frank Wortman, six on that of Anna Walker, four on that of G. T. Riney, five pumpers and one dry hole on that of Alvira E. Sprague, two producers on that of Albert Bainter and one on that of Albert Sprague. The partial record of the Riney No. 5 well follows:

	Thickness in feet.	To top of formation.
Middle Kittanning coal	3	36
Berea sandstone	25	1,025

The oil is in the lower 7 feet of sand, and the production 2 barrels per day.

The Denman Oil Co. has one well with production on the Thomas Bell farm, and the Otsego Gas & Oil Co. one on the Cal Waters land. One well yielding oil on the "Mexican Pete" lot and five on the W. O. Buker property are controlled by J. E. Shaw.

In Section 9 both oil and gas were found by the drill in the Berea, but the quantities produced are not large. Only a showing of oil was obtained in the test drilled by the Denman Oil Co. on the farm of Burt Erman, and similar results were secured by the Otsego Gas & Oil Co. on land of J. M. Bradford. The latter company, however, has one gas well on the Everett Buker property, and the Giles-Harbison Co. has three oil wells on the William Waters land and one gas well on the Everett Buker farm.

Section 10 lies on the east slope of the Otsego anticline. In this area the Berea sandstone thus far has yielded neither oil nor gas in paying quantities. Frank McKee drilled three wells, one with a showing of oil, on the farm of Walter Larntz, one with similar results on that of Rufus Larntz, and one with a showing of gas on that of Decatur Waters. Section 11 lies south of Section 10, and is similarly placed with respect to the rock structure. The Chillicothe Oil & Gas Co. secured a flow of gas in the Berea sandstone on the Fred Wilson land, located in the southeastern part of the area. On this property another test was made by the Muskingum Light & Fuel Co. It gave an initial yield of 175,000 cubic feet of gas, but was never piped. The Giles-Harbison Co. failed to secure production in the well drilled on the W. M. & C. B. Waters farm, and the Otsego Gas & Oil Co. secured similar results on the H. L. Lawrence property.

Section 12 is near the center of the Otsego field and has been thoroughly drilled. In the fall of 1917 the area contained 50 producing and three abandoned oil wells and five tests with only showings of oil or gas. The Otsego Gas & Oil Co. controls 11 producers on the farm of E. L. Mayer; 10 producers and one dry hole on that of G. E. Elliott; one producer on that of Edward Elliott; five on that of Frank Riney; five producers and three tests with showings of oil on that of C. B. Waters; 11 producers on that of G. L. Bradford; two producing and one abandoned well on that of Burt Bradford, and five productive wells on that of Samuel Eckelberry. In this area also the Giles-Harbison Co. has two abandoned wells on the William Waters farm, and McLaughlin Bros. have a dry hole on the James McLaughlin property.

Good production was obtained in the eastern part of Section 13, but only showings of oil with large quantities of brine were found in

the western part of the area, which lies too far down the slope towards the syncline. The Bell Oil Co. has seven and the Giles-Harbison Co. has nine producers on the farm of Nancy and William Walker. Boyce & Co. has five pumpers on the Richard Boyce land, the Giles-Harbison Co. one on that of A. E. Sprague, and one abandoned well on that of W. A. Waters. In this area also John Conner drilled a small well, soon abandoned, on the T. J. Sprague property. No tests have been made in sections 14 or 15.

On the R. I. Buker property, which is located about 1½ miles south of Otsego, the drill operated by the Otsego Gas & Oil Co. failed to secure more than a showing of oil with much brine. Similar results were obtained in the northern part of Section 18 where Forsyth & Bell drilled a test on the Orn Abbott farm. The Berea sandstone in the northern part of Section 19 gave good producing wells, but in the southern part of the area it has yielded neither oil nor gas in paying quantities. Forsyth & Bell owns four producing oil wells on the farm of D. W. Welker, and the Otsego Gas & Oil Co. two producers and one test with a showing of oil on the G. M. Scott property, and one producer on that of Samuel Eckelberry. In one test on the F. E. Brill property Morgan & Inness obtained only a showing of oil, and in another test on the same land McLaughlin Bros. secured similar results.

In the northwestern part of Section 20 the Otsego Gas & Oil Co. has one producing oil well on the G. M. Scott farm, and McLaughlin Bros. have two on the J. E. McLaughlin tract. The tests in the eastern part of the area have not been so encouraging, as only showings of gas or oil have been obtained. There have been three wells drilled, one on the farm of T. M. Low, one on that of J. C. McDonald, and one on that of J. A. Morrow. In Section 21, which is in the southeast corner of the township, both oil and gas have been secured in paying quantities. Anderson & Barnes obtained only a showing of oil on the J. G. Dickson farm, but a gas producer on the D. H. McDonald tract and another on the D. T. Duff property. The initial production of these gas wells is reported to have been about 250,000 cubic feet per day. The small oil pool with four producers is in the southwestern part of the area on land of Elizabeth Acheson and is controlled by the White Eyes Oil & Gas Co. In Section 22 only two tests that reached the Berea sandstone have been made. Walter McLaughlin obtained a showing of oil in the test on the D. H. McDonald farm in the northeastern part of the area, and the Bloomfield Oil & Gas Co. secured but little except brine in the well on the D. Proudfit tract in the southwestern corner of the area. A test in the southwestern part was made on the Bradford Bros. farm, which is located about 3 miles south of Otsego. The well was drilled just south of the tributary of White Eyes Creek by the Barberton Oil & Gas Co. and yielded little except brine.

Adjacent Areas.—As has been previously stated, the Otsego

anticline extends northward into Coshocton County from northeastern Muskingum. In local areas along the anticline both oil and gas have been secured in paying quantities. A part of the main Otsego pool extends northward into sections 23 and 24, Linton Township, Coshocton County, where three producing oil wells and two dry holes have been drilled. Along this same structure the isolated Wertz pool is present in sections 6 and 15, Linton Township. It includes eight producing and one abandoned oil wells and one dry hole. A small gas field is found west of West Lafayette in Lafayette Township, and another with a few wells has been opened recently in sections 18 and 19, Linton Township.

In Knox Township, Guernsey County, a few gas wells and several dry holes have been drilled in the western part of the area along the summit of the Otsego anticline. In the southwestern part of Section 15, two producing gas wells are present, one in the northern part of Section 16, and one along Indian Camp Run in the eastern part of Section 25. In the central and western parts of Section 16, three tests with showings of gas have been made.

BIG INJUN SAND

In Muskingum County the Big Injun sand of the oil driller is the Black-Hand conglomerate, which forms such conspicuous cliffs and escarpments along its outcrop in eastern Licking and Fairfield counties. The rock varies in texture from a coarse-grained sandstone to a rather pebbly conglomerate, but it is always open and porous. In places the bed is broken by layers of shale or shaly sandstone which appear to act as barriers to the circulation of water, oil, or gas. The formation is rather persistent in the county, but it varies greatly in thickness. From drill records the maximum measurement of the bed is about 260 feet, but the usual thickness is only approximately 70 feet. On the average the top of the formation is nearly 525 feet above the top of the Berea sandstone and 2,971 feet above the top of the "Clinton." Further, its position is nearly 175 feet below the base of the Maxville limestone, 316 feet below the top of the Lower Mercer limestone, 385 feet below that of the Putnam Hill limestone, and 465 feet below that of the Middle Kittanning coal. The Big Injun sand commonly contains brines, the largest flow and usually the only one occurring near the base of the formation. The Squaw sand of the southeastern Ohio driller, the position of which is not far below the base of the Big Injun, is scarcely represented in this county. The Keener sand, which is an important source of oil in Washington and Monroe counties, lies about midway in the interval between the Maxville limestone and the Big Injun sand. In the area now under consideration its place is taken by shales and shaly sandstones, which are devoid of either oil or gas, and which seldom contain noticeable quantities of water. No wells have

been drilled in this county in which the Keener, Big Injun, or Squaw sand was sought for, but the many Berea and "Clinton" tests have failed to reveal either oil or gas in paying quantities in the Upper Waverlyan rocks. In a few places small flows of gas have been liberated in the top of the Big Injun sand.

On the Charles Howell farm, about 1 mile south of Philo, a well was drilled with the intention of reaching the Berea sandstone, but owing to difficulties the drill was stopped in the shales below the Big Injun sand. The record furnished by Mr. Howell follows:

	Thickness in feet.	To top of formation.
Gravel	100	-----
Sandstone	100	100
Shale	120	200
Maxville limestone	40	320
Shale	160	360
Big Injun sand	80	520
Shale	-----	600

At a depth of 520 feet a small flow of gas was liberated from the top of the Big Injun sand. Below this the stratum was saturated with salt water which ruined the well. In this test the thickness of the Big Injun sand and its position with reference to the Maxville limestone are about normal for the county. The wellhead is not far from the horizon of the Lower Freeport coal.

POTTSVILLE FORMATION SANDS

At present in Muskingum County neither oil nor gas in paying quantities is obtained in any of the four Pottsville formation sands, the Maxton or Lower Salt, the Middle Salt, the Upper Salt, or the Second Cow Run or 800-foot. In recent drilling small flows of gas have been liberated in a few tests, and considerable quantities of brine have been frequently encountered. In the Dan and Charles Morningstar well, drilled in Section 8, Brush Creek Township, by W. T. Forsyth & Co., about 1,000,000 cubic feet of gas was struck at a depth of 390 feet, or in what appears to be the Massillon or Upper Salt sand. The position of the bed is 210 feet below the Middle Kittanning coal and 752 feet above the Berea formation. The pressure of the gas decreased rapidly and the product was not utilized. In a few wells small showings of gas have been reported in sands near the Mercer horizon. Some of the wells in the abandoned Oil City pool in Bluerock Township are reported to have secured production in a sand about 500 feet in depth, which would place it in the lower part of the Pottsville formation. Most of the oil in this pool, however, came from the Cow Run sand.

ALLEGHENY FORMATION SANDS

The Macksburg 500-foot sand appears to be correlative with

the Clarion sandstone, and the 300-foot or Peeker sand with the Upper Freeport bed of the Allegheny formation. These sandstones in local areas along their outcrops in the central part of Muskingum County have massive development, and from drill records they retain this character in places in the eastern part of the area where they are deeply covered. At present no production is obtained from either bed.

Along Dry Riffle Run in Section 28, Bluerock Township, two wells drilled in 1866 on the farm of I. O. Barr, and one on that of J. J. Bush, probably obtained their production from one of the Allegheny formation sands. The depths are uncertain, but the wells are shallow. These wells are reported to have given a good yield of oil. In 1865 two shallow unproductive tests were drilled on the David Kokensparger farm in Section 4, Bluerock Township. From the depths reported the drill did not descend below the Allegheny formation.

CONEMAUGH FORMATION SANDS

The first discovery of oil in a Conemaugh formation sand in Ohio was in 1861 on Cow Run in Washington County. The bed from which the production was obtained still retains the name Cow Run, and is the most important oil-bearing stratum in the formation. The largest fields developed are in Washington and Morgan counties, but small pools have been secured in adjacent areas. Other well-known sands are the Buell Run, correlative with the Buffalo sandstone, and the Mitchell, correlative with the Connellsville. The Wolf Creek sand also belongs in this formation, but its position has not been definitely determined.

Cow Run Sand

The only sand that needs be considered in this report is the Cow Run, which has been exploited in Union, Rich Hill, Meigs, and Bluerock townships. In local areas this bed is massive, but in other places it is replaced by shales. It forms prominent cliffs along the Muskingum River in Harrison and Bluerock townships, and steep escarpments in parts of Salt Creek, Rich Hill, and Union townships. The position of the Cow Run sand is between the Ames and Cambridge limestones, or, more definitely, between the Anderson and Barton coals. Where well developed, the member lies on or only a few feet above the Anderson coal. On the average the top of the Cow Run sand is nearly 65 feet below the Ames limestone and 42 feet above the Cambridge member. The thickness of the stratum varies from 1 to 40 feet or more, but the average measurement is approximately 20 feet. It is a coarse-grained, loosely-cemented sandstone of a light-gray or drab color. In places the basal portion is somewhat conglomeratic. In some of the deep gorge-like ravines cut in the rock east of the Muskingum River in southern Bluerock Township small quantities of oil were seen seeping from the lower part of the stratum. Some of the

small pools formerly operated in this county were only a few miles east of the outcrop of the sand. The number of wells in this county drilled to the Cow Run sand is uncertain, but it is more than 470. Of these the greater part produced oil in paying quantities. At present but few wells are being pumped and in these the yields are low. Drilling began in 1864, or possibly earlier, but the work was most active in 1865 and 1866.

Bluerock Township.—Concerning the discovery of oil in Bluerock Township, Bownocker says:[1]

> Pioneers of this township observed gas bubbling on the headwaters of Manns Fork, and after oil had been discovered at Macksburg and Cow Run it was decided to drill a deep well in the hope of finding a pool of oil. The first well was drilled on the Daniel Borden farm, and a showing of oil was found at a depth of 80 feet. The next well, known as the Woodbury, was drilled on the Joseph McDonald farm. At a depth of approximately 75 feet oil was found. The yield at first was from 40 to 50 barrels per day, but the decrease was rapid, and by the end of perhaps two years the well was abandoned. This success started a boom, and it is estimated that within a year a hundred wells had been drilled in that locality. A hamlet known as Oil City, and with the usual proportion of boarding houses and saloons, appeared. Within a year, however, it was found that the pool was small and the wells short lived. Soon the field was abandoned, and the only evidence now found of the former activity is an occasional piece of scrap iron, the remains of some crude drill or pump. Landholders received a royalty of one-fourth the oil, but notwithstanding this heavy ratio large bonuses in addition were sometimes paid. Several tracts too were sold at exorbitant prices, one piece of 13 acres commanding $13,000. The oil is reported to have had a gravity of 26 degrees B. and to have been an excellent lubricator. The producing sand ranges in thickness from 2 to 30 feet, and lies about 70 feet below the "fossil" or Ames limestone.

The main part of the old Oil City pool was located in the southwestern part of Section 14. The land owners report that about 25 wells were drilled on the farm of B. S. Peyton, at least 100 on that of R. E. Peyton, and approximately the same number on that of H. B. Hackley. Most of the drilling in this field was done in the years 1865-1866, but since then a few tests have been made from time to time around the edge of the pool up to the fall of 1917. These Cow Run wells gave good initial flows of oil, a few reported as large as 200 barrels per day, but they declined rapidly, and in a few years most of them were abandoned. The depth of the sand, depending on the location, whether in the valley along Manns Fork or on the hills adjacent, ranges from 70 to 250 feet. The oil was found near the base of the Cow Run sand, or about 80 feet below the Ames limestone which outcrops along the banks of the stream. One test was made on the J. W. Peyton farm in the southeastern corner of Section 15. This Oil City pool also extended into the northwestern part of Section 23, where five wells were drilled on the property of Herbert Pyle, and about 25 on that of James Wallace. From here it extended into the northeastern corner of Section 22, where five were put down on the land of F. S. Osborn. No Cow Run tests were found in sections 20, 21, 25 or 26.

[1]Geol. Survey Ohio, 4th Ser., Bull. 1, p. 266.

Along Dry Riffle Run, and on the bordering hills in Section 27, considerable drilling to the Cow Run sand was done as early as 1865, and other tests have been added from time to time. The sand appears at the surface along this stream as far east as the mouth of Coal Hollow, and it has yielded production less than one-fourth mile from its outcrop. The oil is light and of excellent quality. About 1905 Lancaster parties drilled five wells in a row along the road on the land of J. W. Imley. One of these is still producing a little oil. The depths of the tests were only about 50 feet. On the hill north of this two dry holes were drilled and four wells, all producing a little oil at present, along the stream near the eastern section line. These wells are stated to be making about one-fourth barrel of oil per day. Many years ago five additional wells were drilled on this farm, and all yielded small flows of oil. McNally Bros. have two wells, about 50 feet in depth, and yielding nearly one-fourth barrel of oil per day, on the farm of G. S. Betz. A shallow well was also drilled on the Mary Alexander farm south of the mouth of Coal Hollow, and two dry Cow Run tests on the H. N. Roberts tract in the southwestern part of the area.

In Section 33, the Cow Run sand, massive in character, outcrops in the deep ravines in the western part of the area, but under cover in the eastern part it has yielded small flows of oil in a number of places. In these ravines oil may often be seen oozing from the base of the rock. On the J. O. Shilling property, in the northeastern part of the section, four wells, about 150 feet in depth, were drilled many years ago, and two of these were pumped for a few years. Small production was also obtained in four wells drilled on the W. H. Smith property, and in four put down on the A. Finley tract. Considerable drilling to the Cow Run sand has also been done in Section 34, and some oil produced. In the western part of this area, on the farm of J. F. Allen, four wells were drilled about 1865 or 1866, and one of these yielded some oil. Further, small quantities of oil were secured in the Cow Run sand in four wells on the farm of Thompson Jackson. No tests were found in sections 35 or 36.

Meigs Township.—During the Oil City boom in Bluerock Township many small wells were also drilled to the Cow Run sand in Meigs Township. A number of tests were drilled along the streams north of Muscville by James A. Brown. Some of these gave small quantities of oil, which was hauled by wagon to the market. Other tests were made on the property of C. E. James in Section 17, and on those of H. Dickson and J. I. McClure in Section 20. These tests were all shallow, not exceeding 200 feet. The most important Cow Run pool in this township was in Section 6. Along Kent Run, on the J. T. White property, Stevens, Culp Bros., and others, drilled 11 wells, most of which gave small yields of oil. A small flow of gas was found in a test drilled in 1905 on the land of C. T. Gale. Stevens and Gallagher secured a showing of oil in one test, and a little gas in another on the J. S. Fenton farm. On the G. C. Smith property several wells were drilled years ago, and eight

tests were made by C. G. Stevens about 1905. These wells, 80 to 115 feet in depth, gave small yields of oil with some gas. One test was also made by Stevens on the farm of Burt Smith.

Rich Hill Township.—The Cow Run sand has been pierced by the drill at a number of places in Rich Hill Township, but only in local areas has it yielded either oil or gas in paying quantities. The bed forms prominent outcrops in places along White Eyes Creek, Williams Fork, and Buffalo Fork, in the western part of the area. On the Shuster Bros. farm, in Section 12, C. Briggs drilled a Cow Run test about 100 feet in depth, but failed to secure more than a showing of gas. He also drilled two tests with about the same results on the land of Austin Bey, which is located in the western part of this section. In Section 30, J. D. Pearce drilled three wells on the farm of Martin Warne. In the first test the sand was flooded with water, in the second it was broken, and in the third it was absent. The depth of the holes was 120 to 168 feet. One well drilled many years ago on this farm produced a small quantity of oil as did another on the Stewart Fauber farm. About 25 years ago a small pool was discovered on the William Johnson property in the northern part of Section 31, where 113 wells were drilled, most of which produced oil in paying quantities for a few years. In this pool the Cow Run sand was found at depths not exceeding 250 feet. Recently, Miles Okey put down three wells also on this property, but he failed to secure more than good showings of oil. From reports the Cow Run sand in these tests was reached at a depth of approximately 220 feet.

Union Township—The Cow Run sand is above drainage in the western and northern parts of Union Township, but the member is poorly developed in much of the area, as its place is taken so often by siliceous shales. Under cover, however, the bed, with good thickness, has been found by the drill at a number of places and it has yielded small quantities of oil. In Section 14, on the farm of William Walker, a well some 300 feet in depth was drilled about the year 1868, but it failed to give a flow of either oil or gas. Nearly 2 miles due south of New Concord, Anderson Bros. drilled a test about 200 feet in depth for coal on the James Baker farm. At this place the Cow Run sand contained a little oil. In the eastern part of Section 11, Barnett & Sherlock secured similar results in four tests on the land of Adam Anderson, C. Briggs, and H. C. Haines. About 40 years ago two shallow unproductive tests were put down on the Thomas Stewart property in the northwestern part of Section 23, and one on the J. W. Lyons tract in the southwestern part of the same area. On the J. H. Moore farm, adjoining the Lyons property on the east, a well was drilled about 1866 to a depth of nearly 500 feet. The intention was to go deeper, but the tools became fastened and the work was abandoned. This test went below the Cow Run sand, but it failed to secure production in any stratum.

CHAPTER VII

SAND AND GRAVEL

By J. A. BOWNOCKER

MOLDING SANDS

Molding sands, based on their use, are commonly divided into two principal classes, (1) sands for steel castings, and (2) sands for iron castings. The latter class, however, includes brass, bronze, aluminum, and similar metals. Whether a sand is suitable for steel or iron castings depends primarily on its melting point. Sand for steel castings must have a fusion point of 2,900 degrees Fahrenheit, but for iron castings, 2,400 degrees is sufficient.[1]

REQUISITES OF A GOOD MOLDING SAND

The principal requisites of a good molding sand are strength, venting or porosity, and refractoriness, and these depend on the composition of the constituent minerals, their size and shape, clay and moisture. The properties will now be reviewed.

Strength.—The importance of the strength of a molding sand is perhaps self-evident. Strength must be sufficient to withstand the pressure of the metal, for otherwise the mold will be deformed or broken. Manifestly the pressure varies with the size of the casting, and sand that may have the strength for a small body of metal may be wholly inadequate for a large one. Strength depends on the bond, and this usually consists of clay. The strength of the clay in turn is modified by the amount present, its fatness or plasticity, and the moisture. However, the strength is not proportional to the quantity of water which it contains, as after the moisture reaches a certain percentage any further increase appears to weaken the bond. The fatness or plasticity of the clay is readily determined in the laboratory by noting the dye absorption of the clay, or by the quantity of inert material such as sand that it will bond.

Two forms of strength in molding sands are important, crushing and transverse. Crushing strength is the weight necessary to fracture a mass of a specified size, whereas transverse strength is the weight necessary to break a mass supported at both ends. Although both forms are important, the transverse strength is most so because there is more danger of deformation or fracture by this than by radial pressure.

Venting or Porosity.—Molten metal contains gases, and when this material is poured into a mold there must be sufficient venting or

[1]Data by Downs Schaaf of The Buckeye Steel Castings Co.

porosity to permit the gases to escape, as otherwise the expansive force of the gases may rupture the mold and even produce an explosion. Porosity depends on the size and shape of the grains and on the moisture. Angular grains pack more tightly than round ones, which reduces the venting, and where the grains vary in size the small ones occupy the spaces between the large ones, also reducing the cavities. It is stated that a little water acts as a lubricant and, therefore, makes it easier for the gases to escape, but that more water acts in the opposite manner. Experiments, however, show many exceptions to this. Where fluxes, like feldspar, are present they may fuse and form a surface on the casting and thus prevent the free escape of the gases.

Refractory Nature.—Since molten metal has a high temperature, the refractory quality of the sand must be sufficient to withstand this, for otherwise the mold will collapse. The principal ingredient in molding sand is silica (SiO_2), which has a high refractory nature; other minerals present, however, liquify at lower temperatures, and may reduce the refractory nature of the sand to such an extent as to render it worthless for molding purposes. The following figures show the melting point of several of the most abundant constituents of molding sands:[1]

Silica	2912° F.
Plagioclase (anorthite)	2790
Hematite	2372 ±
Magnetite	2300 ±
Muscovite	1230
Orthoclase	2246

Since the fusion temperatures of the sands in Muskingum County are expressed in cones it may be well to state the relation between cones and degrees, and this is given below. It should be kept in mind, however, that time is a factor of importance. Thus a sand which has had a long exposure will fuse at a lower temperature than one with a short exposure. In this work the time was about 3 hours.

Cone.	Degrees Centigrade.	Degrees Fahrenheit.
11	1350	2462
12	1370	2498
13	1390	2534
14	1410	2570
15	1430	2606
16	1450	2642
17	1470	2678
18	1490	2714
19	1510	2750
20	1530	2786
23	1590	2894

[1]Condit, D. D., Trans. Am. Foundrymen's Assoc., Vol. 21, p. 26.

Cone.	Degrees Centigrade.	Degrees Fahrenheit.
26	1650	3002
27	1670	3038
28	1690	3074
29	1710	3110
30	1730	3146
31	1750	3182
32	1770	3218
33	1790	3254
34	1810	3290

Surface of Casting.—It is important to have the casting leave the mold with a smooth surface, and this occurs when the sand is of suitable grain. Thus a coarse sand will give a small casting a rough surface and is therefore undesirable, though it might be satisfactory for a larger casting where the surface is a matter of less importance.

Mold Easily Destroyed.—Molding sands are used over and over again, and it is therefore important that they yield a mold that is easily reduced to sand. If the heat fuses or bakes part of the sand the material cannot be used again until it has been crushed, and this involves additional time and labor.

Preparing Sand for the Mold

The preparation of the sand for the mold is usually a simple matter. If it contains many nodules or pieces of sandstone it must first be crushed, and this is done in a dry-pan or some other simple device. Where sandstone or conglomerate forms the basis of the sand, as is the case at many places in Ohio, crushing is, of course, necessary. After crushing the sand should be screened to remove the large pieces and also to secure uniformity of grain. A few of the sand deposits of Muskingum County and elsewhere in Ohio are so even that they do not even require screening. Such sands are loaded directly on the car and shipped, though they are perhaps always screened before using.

Some sands contain sufficient clay to form the bond and all that may be necessary is to add a suitable quantity of water. Other sands, however, are deficient in clay and in such cases this material must be added, or the sand may be mixed with another one that contains a larger percentage of bond. In steel molding sands the clay is in most cases notably low and various substances are added to form the bond, though clay is by far the most common one.

MOLDING SANDS OF MUSKINGUM COUNTY

Although the two great classes of molding sands may be present in Muskingum County, only those for cast iron and other metals that fuse at a comparatively low temperature are worked.

One of the great sources of steel molding sand in Ohio is the conglomerate or coarse sandstone that lies at or near the base of the Pennsyl-

vanian or coal-bearing strata. Rocks of this age occur in Jackson and Licking townships in the northwestern part of the county, and down the Licking River as far as the western part of Falls Township. However, the conglomerate and sandstone are not well developed in these localities, but the coarse Massillon sandstone, which lies a short distance higher in the geological column, is present with good thickness, and may prove to be suitable for steel castings. Several additional coarse sandstones exist in other parts of the county. One of these is the Homewood which has been quarried in the vicinity of Putnam and South Zanesville. The Clarion sandstone has excellent development from Mill Run north to the mouth of Wills Creek, where Stout says that it has a thickness of from 40 to 50 feet. The Cow Run sandstone is well developed along both sides of the Muskingum River south of Zanesville. Near Otsego, in the northeastern part of the county, the Mahoning and Buffalo sandstones are both well developed, but shipping facilities are lacking.

Muskingum County is the one large producer of molding sands for cast iron, brass, bronze, and aluminum in Ohio, and one of the largest producers in the United States. The market for these sands is large and extends east to Boston, west to San Francisco, north to Canada, and south to the Ohio River. The sands are patchy, but rather widely distributed over the central and eastern parts of the county. They extend north to Dresden, northeast to the vicinity of Adamsville, east to Sonora, southeast to Lawton and Duncan Falls, south to South Zanesville, and west to Putnam Hill. However, the best of the known deposits are at or in the immediate vicinity of Zanesville. In altitude the sands present marked variation. They have been worked at several places in the valley of the Muskingum River, two of which are covered in flood time, and are found also on the tops of the highest hills and at elevations between these two extremes. Expressed in figures the molding sands are found at elevations which range in height from 700 to 900 feet.

DESCRIPTION OF DEPOSITS

On the hill which lies between the Muskingum River and South Zanesville is a large deposit of molding sand that has been used for many years. Edward Ayers reports that he began to work this material as early as 1903. The deposit varies greatly in many respects as will be shown in the following paragraphs.

Pit of the Ayers Mineral Company

The largest deposit of molding sand in this area lies on the northern half of South Zanesville hill, and at an elevation of 900 feet. No complete section of the deposit was visible at any one place when the area was visited in 1917, but George Brady, Superintendent of the plant of the Ayers Mineral Company, who has worked the deposit for the past 15 years, gave the following succession:

Soil	2 feet.
Brown sand. No pebbles. No. 3 sand	8 "
Brown sand. Finer than the above. No pebbles. No. 1 sand	4 "
Gray sand. Coarse, with many sandstone fragments, but no foreign pebbles	15 "
Coarse, sharp sand without sandstone fragments	8 "
Shale, reported.	

All of this material, except the soil at the top and the shale which forms the base, has been used for molding purposes. The two sands which lie below the soil are similar except in fineness of grain and doubtless this varies from place to place. They have the same warm brown color when wet and are entirely free from pebbles or other coarse material. Fresh surfaces show no stratification, but surfaces exposed to rain show a distinct arrangement in layers. These deposits are marketed without milling and by mixing them various grades of fine sand may be secured.

These sands are considered a wind deposit. This is indicated by the fineness of grain, absence of coarse fragments or pebbles, and especially the lack of foreign material. Their presence on other high knobs in the vicinity of Zanesville gives strength to this conclusion. Detailed study of the deposits at this place was not made, but their composition and physical properties may be judged from those of similar sands found elsewhere in the county and whose tests are recorded at the proper place.

Next in descending order is the coarse, gray sand with pieces of shaly sandstone. These fragments which may be counted by the hundreds have a maximum length of 4 or 5 inches and a thickness that in most pieces is less than ½ inch. They are not distributed evenly through the sand, but in places occur in pockets and there form the larger part of the mass. The fragments resemble very closely the coarse shaly sandstone that is so common in the coal measures of the surrrounding country. The sand which contains these pieces is decidedly cross-bedded and its upper surface forms an uneven bed or unconformity with the overlying brown sand. This material, sand and sandstone, is hauled in small cars to the mill where it is crushed and screened and is then marketed as No. 3 sand. See Pl. XI.

The presence of this coarse sand with the pieces of sandy shale 200 feet above the Muskingum River is unexpected. It appears to have been the work of running water before the present hills and valleys were formed and its source was the sandy shale or thin-bedded sandstone of the surrounding country. It is the only hilltop deposit of the kind that has been found in the county and has a small area, perhaps 600 feet north and south by 200 feet east and west.

Microscopic examination of this milled sand was made by Prof. W. J. McCaughey, and the minerals found are listed below in order of their abundance:

1. Quartz,
2. Orthoclase,
3. Microcline,
4. Muscovite,
5. Biotite,
6. Magnetite,
7. Calcite,
8. Hornblende,
9. Tourmaline,
10. Garnet,
11. Oligoclase,
12. Zircon,
13. Chlorite,
14. Epidote.

Chemical analysis of this milled sand was made by Prof. D. J. Demorest. In this work he followed closely the method used by H. E. Field.[1]

Silica, SiO_2	80.66 per cent.
Alumina, Al_2O_3	6.56 " "
Ferric oxide, Fe_2O_3	5.34 " "
Titanic oxide, TiO_2	.60 " "
Lime, CaO	1.00 " "
Moisture at 105° C.	1.27 " "
Ignition loss	2.53 " "

The physical tests of this sand include the crushing and transverse strength, the venting power or permeability to air, the fusion point, and the sieve tests. Tests for the two forms of strength and venting power were all made according to the methods used by the American Foundrymen's Association and the reader is referred to Volume 21 of the Transactions of that society for the details. It may be well here, however, to state that for crushing strength pieces 1 inch square and $2\frac{1}{2}$ inches high were used, whereas for transverse strength the cross section was the same, but the length was $4\frac{1}{2}$ inches and the distance between the supports was 4 inches. The breaking weight in each case is expressed in pounds. The permeability to air is the time necessary to force one gallon of air with a certain pressure through a block of sand 1 inch thick. Sieve tests were made in the usual manner and the results may be found on page 340.

Strength of the Sand in Pounds

	Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
Crushing strength	14.50	4.63	3.99	2.59
Transverse strength	2.61	.17	.20	.18

Permeability to Air in Minutes

Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
.47	1.32	2.33	1.25

Fusion point { Softens at cone 12. / Fuses at cone 14.

True specific gravity, 2.65.

Molding sand has been taken at altitudes of 840 and 800 feet, from two pits that lie between the one just described and South Zanes-

[1]Field, H. E., Trans. Am. Foundrymen's Assoc., Vol. XXI, p. 86.

ville. The sand in these is fine-grained, has a brown color, and is without pebbles or rock fragments of any sort. The material was shipped without crushing or screening.

Pit of the Glacial Sand and Gravel Company

This pit is located at the eastern end of the South Zanesville hill at an elevation of 900 feet or 200 feet above the adjacent valley. A section taken in the pit follows:

Soil	1 feet.
Fine sand, unstratified, mottled, no pebbles or coarse material	11 "
Shaly sandstone, rotten	3 "
Sandstone, rotten	1 "

The entire section, soil excepted, is worked. The material is transported by inclined railway to the mill at the foot of the hill where it is crushed and screened. The rotten shale and sandstone are distinctly stratified and are without doubt in place, that is, have not been transported by water or wind. They must therefore be classed as residual.

About 15 years ago a deposit of fine molding sand was found on the flood plain of the Muskingum River, just below the tube works at Zanesville. The area was small and the thickness only a few feet. By 1915 it had been worked out.

Molding sand was formerly gotten on the top of Putnam Hill at an elevation of 900 feet. The deposit had a maximum thickness of about 6 feet, was fine-grained and of a brown color.

North of Zanesville several deposits of molding sand are worked on the west side of the Muskingum River. One of these is about 1½ miles south of Drake, a station on the Wheeling & Lake Erie Railroad. The deposit is at an elevation of 820 feet and is about 1 mile from the river. The sand has a brown color, contains small pebbles, and shows stratification. It has a maximum thickness of 8 feet. The material is crushed in a dry pan and then screened. This deposit appears to have been made in water as is shown by the pebbles and the stratification.

About a mile north of Ellis, a station on the Wheeling & Lake Erie Railroad, Parr & Son operates a small molding sand pit. The deposit lies on a hillside at an elevation of 850 feet, has a brown color, is without pebbles or other coarse material, and shows no stratification. From 12 to 15 inches of soil covers the sand which has a maximum thickness of 8 feet. The material is fine-grained and may be classed as stove plate sand. It is hauled in wagons without crushing or screening to the railroad, about a quarter of a mile distant. Molding sand was formerly gotten in the Muskingum Valley at Ellis, where work is said to have been started about 20 years ago, and where very recently sand was obtained on the river bank.

The last deposits of molding sand on the west side of the river to be described lie in the vicinity of Dresden. At the south end of that village a bed of brown sand, 4 feet thick, was being worked on a small scale in 1917. The sand is without pebbles, shows no stratification, and resembles that which is found on the hills in the vicinity of Zanesville.

About ¼ mile south of Dresden is another deposit of molding sand which was operated in 1917 by the Dresden Sand Company. The sand has a maximum depth of 9 feet and an average of perhaps 7 feet. The material varies from coarse to fine, and the stratification is conspicuous where the rain has washed out the coarse material. One quartz pebble, nearly 1 inch in diameter, was noted, and several pieces of thin sandy shale were observed in the talus. The material is hauled on a belt conveyor to the mill and reduced in a disintegrator. The sand is marketed as No. 1 and No. 3, the former being used chiefly for aluminum and brass castings and the latter for iron castings. The deposit lies at an elevation of 740 feet and appears to be water lain.

Pit of the Central Ohio Sand and Gravel Company

About ½ mile south of Dresden is the pit of the Central Ohio Sand & Gravel Company. Beneath 1 foot of soil lies from 3 to 5 feet of molding sand. It has a yellow brown color, appears unstratified on fresh surfaces, but distinctly stratified after exposure to rain. Occasional pebbles of granite, quartz, or other rock and pieces of coal were found in it. The material is loaded on cars without crushing or screening and is marketed as No. 1, No. 2, and No. 3 sand. A heavy deposit of gravel is reported to lie beneath the molding sand.

Prof. McCaughey who made a microscopic examination of the No. 2 sand from this pit reported the following minerals which are listed in the order of their abundance:

1. Quartz,	5. Hornblende,	9. Magnetite,
2. Orthoclase.	6. Muscovite,	10. Sillimanite,
3. Microcline,	7. Tourmaline,	11. Epidote,
4. Biotite,	8. Garnet,	12. Rutile.

Quartz and feldspar, he states, are the essential minerals, and hornblende and biotite are the principal accessory ones. The other minerals are found in only small quantities.

Chemical composition[1]

Silica, SiO_2	83.25
Alumina, Al_2O_3	8.11
Ferric oxide, Fe_2O_3	3.14
Titanic oxide, TiO_2	.30
Lime, CaO	.40
Magnesia, MgO	.54
Ignition loss	4.28

[1]Analysis by Prof. D. J. Demorest.

Strength of the Sand in Pounds

	Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
Crushing strength	30.29	11.19	8.51	5.03
Transverse strength	2.95	1.21	.55	.24

Permeability to Air in Minutes

Dry.	With 5% of water	With 7½% of water	With 10% of water
.73	9.42	7.67	1.72

Fusion point { Softens at cone 11. Fuses at cone 12.

True specific gravity, 2.64.

The screen tests may be found on page 340.

MOLDING SANDS EAST OF THE MUSKINGUM RIVER

Molding sands are worked east of the Muskingum River within the corporation of Zanesville, along the Belt Line between Mill Run and Oakland, at Oakland, near Pierce and Lawton on the narrow gauge railroad, and about 1 mile north of Duncan Falls.

Pit of the Zanesville Sand Company

One of the largest and most interesting deposits of molding sand in Muskingum County lies at an elevation of 900 feet on the hill in the northeastern part of Zanesville, and is operated by the Zanesville Sand Company. Where the deposit is thickest, the section is as follows:

	Soil and clay	2½	feet.
4.	Fine sand	4	"
3.	Red sand	4	"
2.	Coarse sand	2	"
1.	Fine sand	10	"
	Clay, unmeasured.		

The basal sand of this section, which varies in texture, is used only for fine castings. Part of it is marketed as No. 0 and is used for brass, but the larger part is disposed of as No. 1, and is used for small iron moldings. It is shipped without disintegrating or screening.

Sand 2 of the section is wedge-shaped and had a thickness of 8 feet at the north end of the pit in 1917. It is not commonly used alone for molding purposes, but when mixed with 50 per cent of sand 4 it makes a No. 2 sand, and when it is mixed with 75 per cent of the coarser part of sand 3 it forms a No. 3 sand. The color of this deposit is mottled or yellow.

Sand 3 has not been marketed alone, but is mixed with other sands from this pit to give the desired constitution. In 1917 it was reported to be changing in texture as excavation into the hill progressed, and the company had hopes of being able to market it as a stove plate or No. 1 sand.

Sand 4 is fine-grained, but not used alone. When mixed with sand 2 it forms a No. 2 sand.

None of the sand in this pit shows stratification on fresh surfaces. Neither pebbles nor fragments of any kind were observed and the foreman reports that none had been found. Viewed as a whole, the face of the pit has a homogeneous appearance. Its color is brown, but in places this is spotted or streaked. The sand is neither disintegrated nor screened, but is loaded directly from the pit into cars and then marketed. This sand is believed to be a wind deposit. Its elevation excludes the theory of water work and its texture and structure are not those of residual materials.

Microscopic examination was made of these sands by Prof. McCaughey and the results follow. The minerals are listed in the order of their abundance.

Sand 1 or Bottom Sand.

1. Quartz.
2. Microcline and orthoclase.
3. Muscovite.
4. Biotite.
5. Tourmaline.
6. Zircon.
7. Plagioclase.
8. Magnetite.
9. Chlorite.
10. Epidote.

Sand from Part 3.

1. Quartz.
2. Orthoclase and microcline.
3. Zircon.
4. Magnetite.
5. Tourmaline.
6. Plagioclase.
7. Epidote.
8. Hornblende.
9. Chlorite.
10. Rutile.

In all, 5 samples were examined, and in each quartz and feldspar are the most abundant minerals. Magnetite varies from fourth to twelfth place. Biotite occupies fourth place in two samples, but in others ranks below tenth place, or is not reported. Muscovite shows similar variation. Hornblende is reported in nearly every sample. As a whole the sands are similar in composition, and the variations are not more than might be expected in different parts of the same bed.

Chemical analyses by Prof. Demorest of these sands gave the following results:

	Silica, SiO_2	Alumina, Al_2O_3	Ferric oxide, Fe_2O_3	Titanic oxide, TiO_2	Calcium oxide, CaO	Magnesium oxide, MgO	Moisture at 105° C.	Ignition loss
Bed 1 or bottom sand	81.76	8.26	2.94	0.90	1.26	.19	.88	2.28
Bed 2 mixed with 50 per cent of bed 4	85.99	5.24	3.75	0.52	1.16	.17	.76	1.50
Bed 3	84.54	5.54	3.60	0.53	1.20	.11	1.40	2.10
Bed 3 mixed with 25 per cent of bed 2	83.10	6.45	4.20	0.46	0.00	.10	1.60	2.30

Crushing Strength

	Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
Bed 1. No. 1 sand	4.96	1.93	3.01	2.15
Bed 1. No. 0 sand	1.82	2.03	2.03	1.56
Bed 2 mixed with 50 per cent of Bed 4. No. 2 sand	5.62	.99	1.32	.99
Bed 3 mixed with 25 per cent of Bed 2. No. 3 sand	17.00	6.97	4.86	2.76

Transverse Strength

	Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
Bed 1. No. 1 sand	.58	.30	.08	.09
Bed 1. No. 0 sand	.37	.08	.09	.08
Bed 2 mixed with 50 per cent of bed 4. No. 2 sand	.21	.08	.00	.00
Bed 3 mixed with 25 per cent of bed 2. No. 3 sand	2.59	.35	.22	.13

Permeability to Air in Minutes

	Dry.	With 5% of water.	With 7½% of water.	With 10% of water.
Bed 1 or bottom sand	1.75	6.70	3.50	3.85
Bed 2 mixed with 50 per cent of bed 4	.25	.37	.58	.20
Bed 3	.38	1.17	.63	.25
Bed 3 mixed with 25 per cent of bed 2	.42	.87	.80	.40

Fusion Point and Specific Gravity

	Softens.	Fuses.	Specific gravity.
Bed 1 or bottom sand	Cone 12	Cone 15	2.62
Bed 2 mixed with 50 per cent of bed 4	Cone 23	Cone 28	2.64
Bed 3	Cone 26	Cone 29	2.62
Bed 3 mixed with 25 per cent of bed 2	Cone 13	Cone 15	2.61

Sieve tests of these sands may be found on page 340.

Sands similar to those just described were worked in 1917 at the north end of Zanesville, directly across the river from the plant of the American Rolling Mill Co. Beneath 2 feet of soil and subsoil lies 8 feet of No. 1 sand with the usual brown color. No pebbles or other coarse material was seen, nor was any stratification observed except where the face had been exposed to rain. The sand was shipped without disintegrating or screening. It lies at an elevation of about 800 feet.

Plant No. 1 of the Burton-Townsend Company

Along or near the eastern limit of Zanesville are numerous deposits of molding sand. Some of these have been worked for many years and others have been developed recently. One of the largest and perhaps the oldest of these deposits is at Plant No. 1 of the Burton-Townsend Co., about one-half mile southwest of Oakland. Work at this place is said to have been started by J. H. Richards about 30 years ago. Later, L. K. Brown operated the plant, and he claims to have built at this place the first successful sand mill in the United States. Shipping sand from the mill was started early in 1902, and the product was used in making gun carriages for the United States Army.

Formerly, about 35 or 40 feet of sand and clay were worked at this place, and there is an exposure of perhaps 30 feet at present. The surface material, which consists of soil and subsoil, and measures 2 or 3 feet, is rejected. Below this lies from 4 to 10 feet of clay, but in places the clay is wanting. The clay is mixed with the sand in the mill and of course serves as a binder.

The sand is distinctly bedded, and in places prominently cross-bedded. It contains many pebbles, and these have a tendency to occur in bands. The pebbles, which are well-rounded, vary in composition; sandstones are the most common, but quartz, flint, and granite were found. Those seen are less than 2 inches in diameter, but the foreman of the plant stated that pebbles 3 or 4 inches in diameter are occasionally found. None were seen or reported in the clay above the sand, but occasionally a piece of coal was found, and thin bands of clay and dark streaks of iron stain were observed in places in the sand. The color of the deposit varies from gray to brown, but these shades grow lighter as the material dries. The coarser sand lies near the base of the pit, and this variety has the gray color. The base of the deposit lies at approximately 820 feet above sea level. That this is a water-laid deposit there can be no doubt. The overlying clay may have been deposited in a similar manner, or it may be the work of the wind.

Milling consists of grinding the sand and clay together in a dry pan and screening the product. By mixing the constituents in different proportions sands of various grades are secured. Moreover, when a particularly coarse product is wanted only the coarsest sand in the pit is used. Occasionally sandstone is ground with the sand or sand and clay. The clay and other impurities in the sandstone form a binder. Some of the proportions used are shown below:

Sand No. 4 (O),	95	per cent of sand and 5 per cent of clay.
Sand No. 4 (L),	75	per cent of sand and 25 per cent of clay.
Sand No. 5 (O),	47½	per cent each of fine and coarse sand and 5 per cent of clay.
Sand No. 3 (L),	60	per cent of sand, 15 per cent of sandstone and 25 per cent of clay.

Sand from this pit is shipped to New York, Chicago, St. Louis, and intermediate places.

Plant No. 2 of the Burton-Townsend Company

Plant No. 2 of the Burton-Townsend Co. is located at Oakland. The sand lies north of the station at an elevation of about 820 feet, and measures from 5 to 15 feet in thickness. The material contains so many pebbles that it might be called fine gravel. Sandstone predominates among the coarse material, but pieces of chert, greenstone, and other igneous forms are common. They are all small, and few measure 2 inches in diameter. The material is distinctly stratified and in places cross-bedded. Its color varies from gray to brown. This deposit also is of aqueous origin. A bed of sand without pebbles has been removed from over the existing deposit. The material was rather coarse and was used in making a No. 4 sand.

Nearby, and a little higher on the slope, is a ledge of about 12 feet of coarse sandstone which is ground with the sand. This rock is very poorly cemented, and on exposure it weathers rapidly to a sandy clay. Higher still, in fact on the top of the knoll at an altitude of about 880 feet, is a thin bed of medium-grained sand which is without pebbles or stratification, and has a brown color. Probably this material was transported and deposited by the wind.

By mixing these deposits in different proportions this plant makes as many as 14 grades of molding sand. In mixing, the parts are determined by estimate. Sand No. 4 is the most important product, and four varieties of this are marketed for castings that weigh from 200 to 2,000 pounds. The mill was erected in 1905, but sand had been taken from the pit at an earlier date.

Two additional plants for molding sand were in operation in 1917 in the vicinity of Oakland. One of these was between Oakland and Mill Run, and the other one was southeast of Oakland on the narrow gauge road. At the latter place about 15 feet of sand was worked. The lower 5 feet consisted of a coarse, sharp, gray material, but the upper part was much less gritty. The deposit appeared to be extensive. Both of these plants were new and the output restricted.

In Salt Creek Township, southeast of Zanesville, deposits of molding sand occur, and in 1917 these were being worked near Pierce and Lawton. The latter deposit lies 1 mile south of the station at an elevation of perhaps 900 feet. Surface material, 2 or 3 feet in thickness, is removed, and below that lies a maximum of 15 feet of molding sand. The material contains no pebbles or other rock fragments. It has the usual brown color of the high altitude sands, and fresh surfaces show no stratification, but where the face has been exposed to rain stratification is readily seen.

A small quantity of molding sand has been obtained at an elevation of about 840 feet 1 mile north of Duncan Falls. The sand has the usual brown color and is without pebbles. No stratification was noted, but the exposure was poor. The deposit has been worked to a depth

NEED OF SYSTEM IN GRADING SANDS

Persons who have read the preceding pages must be impressed with the lack of system in grading molding sands in Muskingum County, and the same is true in other parts of the country. Sands with small numbers are finer than those with larger numbers. Thus a No. 1 sand is finer than a No. 2, and a No. 0 finer than a No. 1, but no one can tell just what the difference between them really is. Neither can it be said that a No. 1 sand produced by one operator is the same as one of similar number produced by another operator, though their pits may be close together. In a way it may be stated that each producer uses a system of his own.

Manifestly, uniformity in classification is needed. The molding sand producers should get together and adopt a system of numbers which would have the same meaning throughout the district at least, and then should make their sands conform to these numbers. This would probably require the screening of all sands, but the confusion which this would avoid would more than compensate for the labor and expense.

Sieve Tests in Percentages

	Over 10 mesh.	Between 10 and 20 mesh.	Between 20 and 30 mesh.	Between 30 and 40 mesh.	Between 40 and 50 mesh.	Between 50 and 60 mesh.	Between 60 and 80 mesh.	Between 80 and 100 mesh.	100 mesh.	Average fineness.
Ayers Mineral Co., No. 3 sand, South Zanesville	1.68	2.61	5.23	39.26	.01	12.05	11.29	.72	27.15	53.61
Central Ohio Sand & Gravel Co., No. 2 sand, Dresden	.03	.18	1.30	4.57	4.42	4.47	7.58	1.53	75.92	87.34
Zanesville Sand Co., Bed 1 or bottom sand. No. 1. sand, Zanesville	.00	.02	.11	.09	.26	.12	1.13	.11	98.16	99.14
Zanesville Sand Co., Bed 2 mixed with 50 per cent of bed 4. No. 2 sand, Zanesville	.00	.01	.04	.51	5.62	11.95	23.62	5.77	52.48	79.65
Zanesville Sand Co., Bed 3, Zanesville	.12	.05	.09	.73	5.05	12.82	25.01	3.05	53.08	79.20
Zanesville Sand Co., Bed 3 mixed with 25 per cent of bed 2. No. 3 sand, Zanesville	.00	.02	.11	1.37	5.17	13.37	22.70	5.98	51.28	78.87

A 10 mesh sieve contains 10 meshes to the inch or 100 to the square inch; a 20 mesh, 400 to the square inch, etc. In the first sand in the table, 1.68 per cent was caught by the 10 mesh, and 98.32 per cent passed through it; 2.61 per cent passed through the 10 mesh, but was caught by the 20 mesh, etc. The percentage of average fineness is only approximate, but serves very well for comparison.

ORIGIN OF MOLDING SANDS

Reference has been made from time to time to the origin of the sands, but it may be well to write a few words for the sake of clearness and in the way of summary. The sands on the hill tops in the vicinity of Zanesville are considered a wind deposit. They are all fine-grained, without pebbles or coarse material of any sort, and have a brown color. Fresh surfaces show no stratification, but weathered surfaces almost invariably show that the material was deposited in layers. The altitude of this sand excludes the theory that it was laid down in quiet water such as a glacial lake, and leaves the wind as the only possible transporting agent. Sand similar to this has been noted elsewhere in Ohio, about 1 mile north of Waverly, Pike County, and in northern Gallia County, where it is now being shipped for molding purposes. These widely scattered places lead to the conclusion that conditions in Muskingum County were by no means local. The source of the sand is believed to have been in the mantle rock that was formed by the breaking down of sandstones whose position was west or southwest of the present sand deposits.

Much of the molding sand in this county lies in valleys, and this commonly has pebbles or other coarse material. Nearly everywhere it is stratified and there can be no doubt of its having been transported and deposited by water. Much of the sand, however, lies above the present high water level and it is believed to have been the work of glacial streams. There is strong evidence that the drainage in the vicinity of Zanesville has undergone extensive changes, and before these were made and while they were in progress, the streams had their beds at higher altitudes. Mixed with this water deposit is sand of eolian origin, for deposition by the wind was by no means restricted to the hill tops. Doubtless much sand that was deposited on the knobs and ridges has been transported by water to lower levels.

A third source of molding sand is the sandstone in the hills of the county. This material is classed as residual, although it was deposited as sediment in water millions of years ago. At present it is worked on the hill that stands between South Zanesville and the river, but nowhere else in the county. However, similar deposits may be found and developed elsewhere, for in the adjacent county of Perry sandstones are worked on a large scale.

GRAVEL

The gravel deposits of Muskingum County occur in the Muskingum Valley and its principal tributary, the Licking.

Gravel has long been worked at Trinway for railroad ballast. Beneath 3 feet of soil lies 15 feet of gravel, and below this sand is reported, though it was not seen by the writer. The gravel is rather fine and pebbles more than 3 or 4 inches in their maximum diameter

are uncommon. The pebbles consist of sandstone, quartz, and igneous material; those of limestone are scarce. As a whole the material appears old and water worn. No fresh exposure was found and hence no stratification was observed. This deposit is too fine for a first-class ballast and it contains too much sand for road building. By screening, it should do very well for mortar and concrete.

The plant of the Zanesville Washed Gravel Co. is located about 2 miles south of Dresden, in the extreme south end of Jefferson Township. The deposit is the coarsest, and probably the best, in the county. It is worked to a depth of 50 feet and the material is carried on a belt to the mill where it is washed, screened, and the larger pieces crushed. Pebbles larger than 5 or 6 inches in diameter are scarce and the gravel as a whole is rather fine. The pebbles consist of igneous rock, gneiss, quartzite, sandstone, and limestone. Igneous pebbles are rather common among the coarser material. Water for washing the gravel is obtained from the river and is forced 1,700 feet through an 8 inch pipe by a centrifugal pump. The material is used for concrete, mortar, and grout. Its market extends as far west as Columbus and east to Cambridge and Dennison. The deposit is extensive.

Directly across the railroad from the mill is a sand deposit that has been opened to a depth of 8 feet. It is stratified and occasionally has small pebbles. The sand in places is rather fine, but a few feet distant it may be coarse. A small quantity of this material has been used for pig bed and has been reported satisfactory. About half way between this plant and Dresden is the pit of the Central Ohio Sand & Gravel Co. The deposit has been worked to a depth of approximately 50 feet and its texture and composition are similar to those of other deposits in this part of the county.

Approximately ½ mile south of Ellis is a mass of gravel which was worked as recently as 1916. The proportion of fine material, however, was large and the plant has been abandoned.

At Gilbert the Glacial Sand & Gravel Co. is working a deposit of gravel to a depth of perhaps 75 feet. The pebbles rarely exceed 4 inches in diameter and the proportion of these is small. The material is mined by a "clam-shell" and is screened. Three grades are shipped, and the principal market is for concrete and mortar with a subordinate call for sand on motors in coal mines.

The "Terrace" at Zanesville consists in large part of gravel, but it is not worked at present nor has it been worked for many years, if at all. Continuing down the Muskingum Valley, gravel is found especially on the east side of the river. Both Duncan Falls and Taylorsville are built on high terraces of this material and at the latter place the deposit has been worked to a depth of perhaps 60 feet. The material is finer than that north of Zanesville. Most of the pebbles

are of sandstone, but igneous forms are common. This deposit is too fine for road building or ballast, but it does very well after screening for concrete or mortar.

The Licking Valley is the only other important source of gravel in the county. On the south side of the valley, across from the infirmary, is a deposit that was being worked in 1917 to a depth of 15 feet. The material is fine, stratified, and cross-bedded, and sandstone is by far the most common pebble. The gravel is screened in a portable mill and 4 grades secured. Concrete is the principal use of the material. Gants Park, at Zanesville, is the site of another gravel deposit. In fact this hill appears to consist of gravel, and it has been worked to a depth of approximately 30 feet. The material is fine and most of it is of local origin. Smaller deposits of gravel are found in this valley farther west and have been worked at several places. However, the material is too fine and has too much sandstone for road building or railroad ballast.

Origin of the Gravel

The gravel of Muskingum County has been derived in part from the sandstone, limestone, and flint of the county and in part from rocks farther north. That of local origin is largely sandstone because this rock is much more abundant than the others.

Although the glacier covered only a small strip along the western border of the county, the principal streams head on the drift-covered surfaces. Such areas contain pebbles from adjacent rocks, from sources farther north, and from Canada. Naturally the streams have carried part of this foreign material and deposited it along their valleys far from the areas covered with drift. It is in this manner that the granite, gneiss, and similar pebbles found their way to Muskingum County. As the pebbles were rolled along the stream beds they were eroded and hence reduced in size. The gravel in the southern part of the county is considerably finer than that in the northern part. Existing deposits of gravel represent only a small part of what the valleys once contained, and much the greater portion has been carried farther down the Muskingum and transmitted to the Ohio River.

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